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Birds in Human Modified Environments and Bird Damage Control: Social, Economic, and Health Implications

by
Anthony J. Krzysik

This report provides a perspective of birds in society and science, provides a descriptive survey of conflicts, problems and economic losses that birds have caused humans, examines potential health and disease risks from birds, identifies the state-of-the-art technologies and methodologies in bird management and control, and provides an extensive and diverse bibliography.

Bird problems are related to one or more of the following categories: (1) damages and economic losses, (2) human health and safety, (3) aesthetics, (4) inconveniences, and (5) competition with native species and brood parasitism. Pigeons, starlings, and house sparrows, all introduced from Europe, and several species of native blackbirds are responsible for most problems in the United States. Most bird management research has been directed to agricultural and feedlot depredations, winter blackbird-starling roosts, and safety hazards to aircraft. Urban bird management strategies have not been adequately researched. Large-scale control measures include habitat modifications, frightening devices, repellents, and wetting agents. Small-scale or local controls include exclusion, toxic baits or perches, live-trapping, frightening devices, and repellents. All of these controls are thoroughly discussed and appraised in this report.

Bird control is a very sensitive public and political issue. The social, scientific, and economic importance of birds must be understood, considered, and realistically appraised whenever a bird management program is planned, developed, and implemented. In any bird control program, all potential environmental concerns or ecological impacts should be thoroughly assessed by qualified personnel, especially when toxins or other chemical compounds are used.

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Bird problems are related to one or more of the following categories: (1) damages and economic losses, (2) human health and safety, (3) aesthetics, (4) inconveniences, and (5) competition with native species and brood parasitism. Pigeons, starlings, and house sparrows, all introduced from Europe, and several species of native blackbirds are responsible for most problems in the United States. Most bird management research has

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Bird control is a very sensitive public and political issue. The social, scientific, and economic importance of birds, and their public attention and popularity must be thoroughly understood, considered, and realistically appraised whenever a bird management program is planned, developed, and implemented. In any bird control program, all potential environmental concerns or ecological impacts should be thoroughly assessed by qualified personnel, especially when toxins or other chemical compounds are used.

Birds represent a potential, although low, health or disease risk for humans. Most avian pathogens or parasites only affect other birds and host specificity is often high. Pets, poultry, game species, and aviary specimens have been affected in epidemics. The most important human diseases associated with birds in the United States are histoplasmosis, encephalitis, chlamydiosis (parrot fever), and cryptococcosis.

FOREWORD

The study reported here was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), under Civil Works Research Work Unit 32333, "Control of Roosting Birds and Bird Waste," for which Dr. Anthony J. Krzysik is Principal Investigator. Funds for this work were provided through the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program, Research Area, "Miscellaneous Maintenance and Repair of Hydraulic Structures and Equipment."

This report is an expanded and updated version of REMR Technical Report REMR-EM-1/ADA190195, September 1987 (Krzysik, 1987a). The REMR report was directed primarily to Civil Works projects. The present report includes numerous additional references and discusses in more detail several aspects of avian management: social and scientific implications, agricultural depredations, and health hazards. A new section dealing with the potential health hazards of avian ectoparasites has been added.

Thanks to Mr. Robert Whiting (St. Paul District), Mr. Carl Cable (North Central Division), Mr. Harold Lawson (Detroit District), Mr. Gerard Mick (Omaha District), Dr. Donald Mott (Department of Agriculture), Mr. Ronald Ogden (Department of Agriculture), and Mr. Chester Martin (CEWES-ER-W) for their excellent review of the earlier draft of this report. Their comments appreciably improved the clarity and organization of the report, as well as provided insight into novel avian management strategies.

Special thanks are due to Ed Cleary, Jim Forbes, Mike Hoy, Jeff Jones, Dwight LeBlanc, Don Mott, Dave Otis, and Ed Penrod, all of the Avian Damage Control Section of the Department of Agriculture, for sharing their knowledge and experience with me concerning bird problems and management strategies. This report has benefited a great deal because of their influence.

This work was conducted by the U.S. Army Construction Engineering Research Laboratory (USACERL) during the period November 1984 to July 1988 under the general supervision of Dr. R. K. Jain, Chief of the Environmental Division. COL Carl O. Magnell is Commander and Director of USACERL, and Dr. L. R. Shaffer is Technical Director.

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1 INTRODUCTION

Background

Bird control is a sensitive public and political issue, since people possess a strong appreciation and affection for birds. The public does not want to see dead birds, even when the birds are present in excessive numbers or are the known cause for specific health problems or economic losses. There is increasing concern over the humane treatment of animals (Kellert 1978, 1980, Kellert and Berry 1980, Schmidt and Bruner 1981), and public attitude may remain unswayed even with ecologically based arguments aimed at controlling pest species.

Public response is more favorable toward the use of repellents, frightening devices, exclusions, or live-trapping and transplanting. However, these methods are often impractical or ineffective. The informed public is more tolerant of control measures directed at introduced nongame species (e.g., pigeons, starlings, house [English] sparrows, and monk parakeets) as contrasted to targeting native birds. If toxicants are employed, they should be slow acting in order for the birds to disperse before succumbing. However, this strategy presents the problem of secondary toxicity to predators or scavengers feeding on dead or dying birds.

There are no Federal regulations for controlling exotic nongame species. Although migratory species are protected by Federal law, a Federal permit can be obtained to control birds doing economic damage. Blackbirds, grackles, cowbirds, crows, and magpies can be taken without a Federal permit when they are committing or about to commit depredation to agricultural crops, livestock, wildlife, ornamental or shade trees, or when they are concentrated in such numbers that they constitute a nuisance or health hazard (Cleary 1988). Federal or state threatened/endangered species may not be killed or harassed at any time regardless of their actions. However, state regulations vary (Cleary 1988). Many state laws (e.g., Indiana and Kentucky) mirror Federal law. Pennsylvania and Kansas give protection to all birds and require a state permit before any bird is taken. At the local level, many urban and metropolitan areas (e.g., Washington, D.C.) are classified as bird sanctuaries where no birds may be taken. Additionally, the use of chemicals for repelling or killing birds is under the regulation of Federal and State Environmental Protection Agencies.

The social, scientific, and economic importance of birds, and their visibility and popularity with the public must be thoroughly understood, considered, and realistically appraised whenever a bird management program is planned and implemented. For example, this is apparent at Civil Works facilities, where the public and the Army Corps of Engineers interface. Additionally, potential environmental impacts should be thoroughly assessed during the planning stages of any bird control or management program. This is particularly important for habitat modifications, or when using chemicals or toxins whose environmental fate is unknown.

Most problem birds in the United States represent either introduced species or native populations which have grown excessively as a direct consequence of

deforestation, extensive agricultural monocultures, decreased predation, and a variety of manmade habitat changes in the landscape. Starlings and house sparrows (imported species), combined with huge population increases in several native species of blackbirds, have been a detriment to many native bird populations. Numerous native species are becoming uncommon or rare because of strong competition (or brood parasitism) with their numerically abundant and more aggressive neighbors.

Contrary to blackbird and edge species, many native bird species have been deleteriously affected by landscape changes, particularly forest fragmentation. The size of undisturbed forest tracts and their proximity to other forest tracts are more important factors for most species of eastern forest birds than any measurable features of the habitat (Robbins et al. 1989). Forest fragmentation is the primary threat to the North American forest avifauna (Forman et al. 1976, Galli et al. 1976, Lynch and Whitcomb 1977, MacClintock et al. 1977, Whitcomb 1977, Briggs and Criswell 1979, Robbins 1979, Butcher et al. 1981, Whitcomb et al. 1981, Ambuel and Temple 1982, Hall 1984, Lynch and Whigham 1984, Wilcove 1985a, 1988). Forest fragmentation increases nest predation (Robbins 1980, Ambuel and Temple 1983, Noss 1983, Wilcove 1985b, Yahner and Scott 1983) and cowbird parasitism (Lowther and Johnson 1977, Brittingham and Temple 1983); reduces critical microhabitats (Lynch and Whigham 1984) and food resources (Blake 1983); and creates unfavorable biogeographic equilibria, low colonization rates and high extinction rates (Whitcomb et al. 1981). Additionally, the recent extreme deforestation in the New World tropics may be having serious impacts on overwintering neotropical migrants, which are mainly forest interior species (Aldrich and Robbins 1970, Briggs and Criswell 1979, Terborgh 1980, Ambuel and Temple 1982). However, some researchers feel that neotropical deforestation has come into equilibrium with forest losses in the United States. Since neotropical forests are being lumbered at a higher rate than their northern counterparts, in the future there will be less winter habitat available than breeding habitat (Myers 1980, Wilcove and Terborgh 1984, Wilcove 1985a, 1988).

Since the common names of birds are well known and consistently used through the country by both the public and biologists, only common names will be used in this report. Scientific names of most species discussed are given in Appendix A. Scientific names can also be found in any of the commonly available field guides.

This report is an expanded and updated version of an earlier REMR Technical Report (Krzysik 1987a). The REMR report was directed primarily to Civil Works projects. The present report includes numerous additional references and discusses in more detail several aspects of avian management: social and scientific implications, agricultural depredations, and health hazards. A new section dealing with the potential health hazards of avian ectoparasites has been added.

Objectives

There are four objectives in this report:

1. Provide a review of bird problems and give examples of bird damage.

2. Discuss current methods and state-of-the-art technologies in bird management and control.

3. Provide a perspective of birds in society and science.

4. Provide extensive and diverse references for background information, as a bibliography for problem solving, and as a foundation for initiating specific research objectives.

Approach

For this phase of work, an extensive literature survey was made, which included a computer search (Dialog Information Services - Biosis Previews, National Technical Information Service). Particular attention was addressed to conference proceedings dealing with bird management and wildlife damage control. Chapter 2 provides a background and perspective on the social, economic, and scientific values of birds. Chapter 3 summarizes the problems and economic damages caused by bird pests. Chapter 4 reviews the potential health hazards of birds as disease vectors. Chapters 5 and 6 used in conjunction provide specific management recommendations or guidelines for species specific bird problems. Chapter 7 is the summary.

2 A PERSPECTIVE OF BIRDS IN SOCIETY AND SCIENCE

Nonconsumptive wildlife recreation (e.g., feeding, observing, photographing, and nature study) has become one of the most popular and important recreational activities in this country in terms of the number of participants, as well as dollar expenditures (U.S. Department of the Interior 1982, Outdoor Recreation Policy Review Group 1983, Lyons and Leedy 1984, Werner and Tylka 1984) and in Canada (Butler 1984, Canadian Wildlife Service 1984). Even in Canada, not only does participation in nongame wildlife activities far exceed participation in fishing and hunting, but the nonconsumptive majority fund 60 percent of the Fish and Wildlife Division's budget (Butler 1983, 1984).

Birds are undoubtedly the single most important component of nonconsumptive wildlife recreation, as well as State, U.S. Fish and Wildlife Service, U.S. Forest Service, and other Federal nongame wildlife programs. Enthusiastic members of the numerous local chapters of the National Audubon Society, scattered throughout all 50 states, attest to the popularity of bird watching as a hobby or avocation. Bird watchers also form a strong core within other environmentally aware and oriented organizations such as the National Wildlife Federation, Nature Conservancy, Sierra Club, and Wilderness Society. The strong public grassroots support within these organizations has provided substantial economic and political motivations for environmental legislation, as well as public participation in the processes and issues involving Environmental Impact Statements and the National Environmental Policy Act (NEPA).

The strong public attraction to birds is attributable to many factors. Unlike most other animals, birds are conspicuous both visually and vocally; most species possess attractive or ostentatious color or form; many possess an attractive song; flight has always intrigued man; and birds are abundant, diverse, and widely distributed, being found in all conceivable habitats. Birds, therefore, are a critical component of "the outdoor experience," whether it be hiking, camping, fishing, hunting, canoeing, or just barbecuing in the back yard. Reflect for a moment how it would seem outdoors, even in the winter, without seeing or hearing a bird. Even individuals who do not regularly participate in outdoor recreation nevertheless enjoy and appreciate birds in their surroundings. This is reflected in the huge sales of bird seed, feeders, and houses (U.S. Dept. of the Interior 1982, Leedy and Adams 1984). Twenty to 30 percent of U.S. households feed birds (More 1979). Even grocery stores and discount department stores carry a full supply of wild bird seed. A 1980 survey (U.S. Dept. of the Interior 1982) indicated that 5.4 million people in New England and 13.0 million in the Middle Atlantic states fed wildlife (mainly birds). In these same regions about 4.5 and 9.9 million residents, respectively, observed or photographed wildlife. Nonconsumptive wildlife recreation, centering mainly around birds, was engaged in by more people (94.6 million) than fishing (53.9 million) and hunting (19.4 million) combined (U.S. Dept. of the Interior 1982).

A survey taken in Guelph, Ontario of city dwellers' attitudes toward urban wildlife, disclosed that 70 to 77 percent (three study groups) of the people preferred having birds on their property, as contrasted to negative or neutral opinions (Gilbert 1982). On the contrary, only 25 to 49 percent of the same groups preferred having mammals around. The same survey reported that 27 to 49 percent of the respondents regularly utilized bird feeders, spending up to $100 per year on bird seed. Other surveys reached similar conclusions (Dagg 1970, DeGraaf and Payne 1975, Brown and Dawson 1978, Shaar 1979).

In a 1982 survey at Columbia, Maryland (Adams et al. 1984), 98 percent of the residents said they enjoyed viewing birds and other wildlife. Additionally, 94 percent of

future stormwater control basins for fish and wildlife, in addition to flood and sediment control. Also, 73 percent of the home owners said that they would be willing to pay more for property located in a neighborhood possessing permanent water basins managed for fish and wildlife.

Nonconsumptive wildlife recreation, therefore, possess a firm economic basis. Products used by participants include: photography equipment, binoculars, field guides and other books, outdoor equipment and clothing, and the numerous and diverse products and services associated with travel and lodging. Sixty-two percent of wildlife observers in southern Arizona estimated the equipment they used primarily for nonconsumptive wildlife recreation was valued between $100 and $1500, while 7 percent valued their equipment at over $5000 (More 1979). In a 1982 survey (Butler 1984), Canadians spent $4.2 billion on wildlife related activities. Half of this money was spent directly for nonconsumptive wildlife recreation. About 84 percent of all Canadians had participated, at least individually, in wildlife-oriented activities. Birds were the most important component of the wildlife experience for Americans as well as Canadians. Interestingly, all this attention on nonconsumptive wildlife recreation has resulted in negative environmental impacts (Willard and Marr 1970, Liddle 1975, Bayfield 1979, Ream 1980, Cole 1985, 1987, 1988, Boyle and Samson 1985, Kuss and Graefe 1985, Price 1985).

There has been a concerted effort and increasing enthusiasm for wildlife inventory and management in urban/suburban environments, with a strong emphasis on birds (Thomas and DeGraaf 1973, Doxiadis 1974, Guthrie 1974, Noyes and Progulski 1974, Euler et al. 1975, DeGraaf and Thomas 1976, Vale and Vale 1976, Leedy et al. 1978, 1981, Washington 1978, Lancaster and Rees 1979, Leedy 1979, Figley and Van Druff 1982, Adams and Dove 1984, Leedy and Adams 1984, Adams et al. 1985a, 1985b).

An important economic benefit of birds, including pest species, is their enormous appetite for insects. Red-winged blackbirds consume corn borers, rootworm beetles, cutworms, and earworms, all serious pests of corn (Genung et al. 1976, Dolbeer 1980, Bendell et al. 1981). McAtee (1920) listed 70 instances of local exterminations of insects and other pests by birds. Woodpeckers controlled an outbreak of bark beetles in Colorado (Olson 1953). At some localities 75 percent of the beetles were consumed, and 90 percent of the stomach contents of several woodpeckers consisted of bark beetles. Starlings are primarily insect foragers, having a significant impact on lawn and garden pests. They feed heavily on Japanese beetles, cutworms, grasshoppers, and lawn grubs, and are the most effective control for clover weevils (*Hypera*, Coleoptera) (Terres 1980). Additionally, some avian species consume large quantities of weed seeds (e.g., cowbirds and red-winged blackbirds [White et al. 1985]).

Hawks and owls feed heavily on rodents and are an important check in regulating population numbers in these pests. These predators are particularly effective population regulators when rodent population cycles are at their low point. Kestrels (sparrow hawks) show a high preference for grasshoppers and locusts when they are available. Peregrin falcons are important predators of pigeons when their eyries are located on urban buildings.

Birds are committed to their heavy consumptions because they must maintain a high body temperature (about 42 °C for most songbirds), they possess a high basal

metabolism,* flight requires large expenditures of energy, and small birds possess a high surface to volume ratio (although the feathers and down of birds are excellent insulators, they must maintain a temperature gradient that may exceed 50 °C over very short distances). Insects** are fed to nestlings, since they require large amounts of protein for rapid growth. Bird species that are omnivores, frugivores, or granivores*** outside of the nesting season, (e.g., blackbirds, grackles, cowbirds, sparrows), nevertheless become insectivores themselves and feed their young exclusively (or nearly so)+ insects. Appendix B gives some examples of food consumption by birds.

A little acknowledged asset of some avian species (e.g., hummingbirds) is their role in flower pollination. Pollinators are known as keystone species, since their importance in the structure and function of communities is far greater than their biomass or energy flow indicates.

Scientifically, birds have been among the most intensively studied group of organisms. Taxonomically, birds represent the best known class in the animal kingdom. Birds also represent the best studied group of animals by non-professional biologists. The seasonal Christmas and breeding bird censuses (published in *American Birds*) are only one important example of the numerous contributions made by bird enthusiasts.

Birds have been the prime subjects in both empirical and theoretical ecological research. In addition to practicality and aesthetics, birds are of high interest ecologically for several critical reasons. Birds display a broad diversity of ecological roles (niches). Not only are birds abundant, but a large number of species can be found in the same habitat, many of them possessing very similar ecologies. Therefore, they make excellent candidates for research dealing with resource++ partioning, competitive interactions, foraging strategies, and behavior. Studying and quantifying these components is easier and more practical with birds than with other animal groups, since birds

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*Basal metabolism is the required energy expended by an organism when it is at rest. Metabolic rates increase inversely with body weight in an exponential fashion. Therefore, the small songbirds have proportionally much greater nutritional demands than large (chicken-sized) birds.

**A more accurate term would be arthropods, which includes insects, arachnids (spiders, etc.), crustaceans (crayfish, sowbugs, etc.) chilopods (centipedes), diplopods (millipedes), etc. Annelids (earthworms), mollusks (snails, bivalves, etc.); or vertebrates may be important protein sources for some species. Parental pigeons/doves and goldfinches forage primarily on seeds or grain. Pigeon or dove nestings are fed regurgitated "pigeon milk" by both sexes. Goldfinches feed their young partially digested seeds.

***Omnivores - unselective diet; insects, seeds, fruit, etc. are all utilized depending on relative availability. Granivores - feeding on seeds, grains, or nuts. Frugivores - feeding on fruit.

+Although most species feed their nestlings exclusively high protein items (see footnote**), waxwings feed their nestlings an appreciable amount of berries and occasionally thrushes have been observed to feed their young berries.

++Resources represent environmental components that are necessary for species survival or reproduction (e.g., food or nutrients, nest sites or materials, courtship or mating areas, shelter, hibernacula, or other habitat components). Environmental resources are generally in limited supply spatially and/or temporally.

can be observed foraging,* nest building, feeding nestlings, and socially interacting during daylight hours. Most mammals, reptiles, and amphibians are nocturnal or fossorial. Fish and invertebrates are difficult to study since there are usually serious observational problems.

Modern community ecology began with MacArthur's (1958, 1968) work with New England warblers, and birds remained his subjects for developing the foundations of theoretical ecology (MacArthur 1965, 1969, 1970, 1971, 1972, MacArthur and MacArthur 1961, MacArthur et al. 1966, MacArthur and Levins 1967). Birds have continued to be subjects for studying competition (Colwell 1973, Davis 1973, Cody 1974, 1978, Diamond 1975, Terborgh and Weske 1975, Morse 1976, 1985, Williams and Batzli 1979, Grant and Schluter 1984, Brown and Bowers 1985); and island biography (MacArthur and Wilson 1967, Diamond 1969, 1974; MacArthur et al. 1972, Terborgh 1973, Abbot 1975, Wilson and Willis 1975, Diamond et al. 1976, Diamond and Mayr 1976, Butcher et al. 1981, Temple 1981). Although Diamond's (1969) report is in serious error, as correctly discussed by Lynch and Johnson (1974), it undoubtedly had a strong influence on the large influx of publications in the late seventies and eighties (particularly from the "Florida Group") addressing and testing MacArthur and Wilson's (1963, 1967) island equilibrium hypothesis (e.g., Simberloff 1976a, 1976b, 1978, Brown and Kodric-Brown 1977, Abele and Connor 1979, Connor and Simberloff 1979, Strong 1979, Gilbert 1980, Kuris et al. 1980, Strong and Rey 1982, Rey 1984).

The early community oriented bird studies have initiated similar research with other vertebrate groups: mammals (Rosenzweig and Winaker 1969, Rosenzweig and Sterner 1970, Heller 1971, Grant 1972, Brown and Lieberman 1973, Brown 1975, Price 1978, Patterson 1981); lizards (Schoener 1968, 1975, Schoener and Gorman 1968, Pianka 1973, 1975, Huey and Pianka 1974, 1977, Pianka et al. 1979, Dunham 1983); snakes (Mushinsky and Hebrard 1977a, 1977b, Hebrard and Mushinsky 1978, Brown and Parker 1982, Fitch 1981); frogs (Inger and Greenberg 1966, Toft and Duellman 1979, Toft 1980, Jones 1982); salamanders (Jaeger 1970, 1971, Fraser 1976, Krzysik 1979, Hairston 1980a, 1980b); and fish (Zaret and Rand 1971, Werner 1977, 1984, Keast 1978, Bohnsack and Talbot 1980, Sale and Williams 1982, Sale 1984).

Recently the U.S. Forest Service (Department of Agriculture) has recognized the importance of nongame bird species, not only as a natural resource in themselves but as valuable indicators of timber, range, and watershed management practices (Smith 1975, Scott et al. 1977, DeGraaf 1978a, 1978b, 1979, 1980, Szaro and Balda 1979, Zarnowitz 1982, Davis et al. 1983, Dickson et al. 1984).

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*Important foraging resource components for birds represent not only the type and size of food items, but include foraging substrates (e.g., foliage, bark, ground, litter, air, water, etc.); foraging manuevers (e.g., gleaner, hoverer, prober, driller, picker, sallier, hawker, diver, etc.); and foraging heights.

3 BIRD PROBLEMS

Introduction

Despite all their benefits, birds have also provided man with problems. These problems are usually related to one or more of the following categories: (a) damages and economic losses, (b) public health and safety, (c) aesthetics, visual and acoustic, (d) inconveniences, and (e) competition with native species, particularly for nesting cavities,* and (f) brood parasitism.

Generally, bird problems are of a highly local nature and usually only a few bird species are responsible. Three introduced species** closely associated with man and his urban landscape are responsible for the majority of local problems—common pigeon or rock dove, European starling,*** and the house or English sparrow. (See Appendix A for the scientific names of most bird species cited in this report.)

Two native species, the common grackle and the red-winged blackbird,+ have dramatically increased their populations and distributions in modern times. This is most likely attributable to deforestation, the increase in ecotones (edges), and the large-scale habitat changes man has made in the landscape, particularly the increase of grain crops. These birds find an almost infinite supply of grain in agricultural fields (including ones already harvested) and livestock feeding pens. These feeding areas, especially livestock pens, are particularly necessary during severe winter weather. The availability of adequate and predictable winter food resources may have been the limiting factor on blackbird populations in the past. Decreases in the predators and competitors of blackbirds may also be attributable to man-dominated landscapes and may in part also contribute to their newly achieved success. Red-winged blackbirds are the most abundant bird species in North America.

Brown-headed cowbirds have also benefited from modern land-use patterns since they are an edge species, and are also commonly associated with cattle and horses. Cowbirds feed heavily on weed seeds and have not been implicated in economic losses as

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*Starlings and house sparrows are cavity nesters. Occasionally, house sparrows will build colonial large round straw domes in dense thorny shrubs or small trees.

**Dates of successful introductions into the U.S. from Europe (Terres 1980); Pigeon (1621), house sparrow (1853), starling (1890).

***Hill mynas and crested mynas belong to the starling family (Sturnidae) and have been introduced into Florida and the Pacific Northwest, respectively. The hill myna has the reputation of being one of the best talking birds in the world.

+Taxonomically, blackbirds are a subfamily of birds (Icterinae) that includes bobolinks, meadowlarks, orioles, grackles, cowbirds, and blackbirds. Other species with blackbird in their common name in addition to the red-winged are: Brewer's, rusty, yellow-headed, and tricolored. Of these five species, the red-wing is by a great margin the most abundant and widely distributed. It is also the most abundant species of icterinid (Meanley and Royall 1976). The red-wing, along with the common grackle, brown-headed cowbird, and European starling (Sturnidae), usually comprise 95 to 99 percent of the infamous winter roosting flocks that often contain over a million individuals. The use of the term blackbird in this report will collectively refer to three species: red-winged blackbird, common grackle, and brown-headed cowbird.

frequently as other blackbirds. However, cowbirds are brood parasites,* and they may do severe damage to songbird populations, since forest fragmentation encourages parasitism to forest interior bird species (Lowther and Johnson 1977, Brittingham and Temple 1983). There are well documented cases of their effect on the nesting success of endangered species: Kirtland's warbler (Mayfield 1978, Kelly and DeCapita 1982); black-capped vireo (Grzybowski 1988, David Tazik, personal communication); and golden-cheeked warbler (Pulich 1976).

Specific Species

Pigeons, Starlings, and House Sparrows

The common pigeon or rock dove, the European starling, and the house or English sparrow are three species introduced from Europe that are responsible for the majority of local nuisance bird problems. All three species are abundant, familiar, and closely associated with man throughout the United States (Summers-Smith 1967, Kendeigh 1973, Weber 1979, Feare 1984). Even in the inhospitable Mojave Desert, starlings and house sparrows can be found, but only in close association with man and his modified environment. These two species are completely absent from adjacent desert habitats whenever they are present at small, remote, human-inhabited installations (Krzysik, unpublished data). The rock dove was the first bird to be domesticated (4500 BC) and has been distributed worldwide (Zeuner 1963). The house sparrow has filled the avian urban niche and can be found in all settled areas of the world with the exception of China and Japan (Campbell and Lack 1985). The starling's original range was Europe and western Asia, but it has become abundant when introduced into temperate and Mediterranean regions: United States, southern Canada, southern Africa, southern Australia, New Zealand, and numerous islands (Feare 1984). Although these species cause problems mainly in the urban environment or with man-made structures, starlings are also responsible for depredations at livestock and poultry feedlots (see Feedlots, p 26) and damage to newly sprouted wheat (Stickley et al. 1976a, Dolbeer et al. 1979).

These three species are responsible for the majority of bird damage, nuisance, and health problems at U.S. Army Corps of Engineers projects (Krzysik 1987b, 1988). These projects represent a wide variety of facilities including: locks and dams, power stations, bridges, buildings, and reservoirs.

Urban Settings. Most people are quite familiar with the visual effects of pigeons, starlings, and house sparrows on buildings, automobiles, and virtually all structures associated with the urban landscape. Superficially the problem is aesthetic, but more serious is the economic damage caused by their acidic excrement. Metal and concrete

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*Cowbirds, as well as some members of four additional families of birds do not build nests, but lay their eggs in the nests of other species. The nestlings of the parasitic species, because of aggression or early egg hatching, are at a competitive advantage for obtaining food and therefore grow faster. Their rightful nest mates become undernourished and succumb to parasites or weather, or are pushed out of the nest by the larger cowbirds. It is not unusual to see adult warblers feeding newly fledged cowbirds that are several times larger than their adopted parents. Brood parasitism is more prevalent in tropical than in temperate regions. In some instances, brood parasitism benefits nestlings, since their parasitic nestmates feed extensively on fly larvae that heavily parasitize the host nestlings (Smith 1968). In this instance, parasitized nests have a higher fledgling rate than those unparasitized.

surfaces, paints and coatings, limestone, marble, and electrical components are only a few examples that are susceptible to severe damage or decay. Structural damage, equipment failure, and slippery ledges or walkways are potential safety hazards resulting from bird excrement. Additionally, bird droppings may pose serious health hazards, especially for histoplasmosis, cryptococcosis, and chlamydiosis (see **Birds as Potential Disease Vectors,** p 28).

Pigeons commonly nest on building ledges, air conditioners, roofs, bridge girders, or any available elevated flat surfaces. However, pigeons have occasionally nested in trees (Peterson 1986). Starlings and house sparrows are cavity nesters, and a common problem concerns their nests being constructed in undesirable places such as air vents, inlets, or breathers; rain spouts; under awning edges; cracks or crevices in walls and around windows or doors; under eaves; and in electrical, hydraulic, or mechanical equipment. Usually the nest itself is the problem, but excrement or noisy birds may be a more serious consideration since these species are often colonial. Starlings and house sparrows compete with native species for nest cavities since these are usually a limited resource. Competition with bluebirds is particularly severe because of similarities in body sizes and habitat selection.

Buildings. Pigeons, starlings, and house sparrows often nest within large buildings such as warehouses, boathouses, and airplane hangars. Severe and costly damage from their excrement occurs in hangars since cockpits are opened and engines, electrical/ electronic components, and hydraulic systems are being maintained or repaired out in the open (Will 1985). Occasionally planes must be repainted because of corrosion or chipping paint. A small Air Force fighter plane requires over $1,000 in paint and supplies and about 800 manhours to paint. Occasionally the birds build nests among mechanical, electrical, or hydraulic components when equipment is being maintained or the cockpit is open. The nests interfere with moving parts and create a fire hazard. (See Urban Settings, p 15, for additional problems caused by bird excrement and nests.) Starlings often nest within fiberglass or styrofoam insulation, causing extensive damage within building roofs and walls (Hail 1985).

Birds, their nestlings, and their nests usually carry large numbers of ectoparasites. Thousands of workers in an Air Force hangar in Oklahoma were affected by bird mites (Will 1985). Pigeons were the most abundant pest species, but starlings and house sparrows were also present. Similarly, personnel entering the boathouse at Dale Hollow Lake, Tennessee (Nashville District, COE) were covered by bird mites from resident nesting starlings (James Hunter, personal communication). Bird mites are irritating and some people show an allergic reaction, but members of the family Sarcoptidae (itch or scaly-leg mites) can be skin parasites of dogs and man (Terres 1980).

Bridges. Pigeons are commonly associated with bridges. Their natural roosting and nesting places were high rugged cliff faces with abundant flat ledges in otherwise open habitat. Pigeons will not use round perches and they avoid dense vegetation. The flat perches of the structural components and girders of bridges, along with completely open surroundings, represent optimal pigeon habitat in man-modified environments. The structural integrity of bridges is of prime concern, but aesthetics is also important, and excessive bird excrement may be a serious economic problem. Sandblasting, priming, and painting bridge structures is very costly because of the difficulty and safety risks involved.

Dam and Lock Complexes. Locks, dams, powerhouses, and all their associated structures provide an unusually rich source of nesting and roosting sites for pigeons, starlings, and house sparrows. Pigeons need flat surfaces in open areas. Since pigeons

are large birds and usually abundant around these structures, their excrement may create serious aesthetic, health, safety, and corrosion/deterioration problems.

Starlings and sparrows are cavity nesters and therefore find an unlimited source of nooks and crevices at these installations. The typical problems of starlings and sparrows at locks, dams, and cranes is that their nests or associated excrement may impair or contribute to the failure of mechanical (movable parts) and electrical or hydraulic equipment. Therefore, they may create safety or fire hazards. The earlier sections, Urban Settings, Buildings, and Bridges also discuss relevant information for lock and dam bird problems.

Gulls

Prior to 1900, gulls were relatively uncommon along the Atlantic Coast south of Maine. However, since 1945, gull populations have greatly increased and have extended their range to the Gulf Coast (Forbes 1988). Herring gulls, formerly limited to nesting in New England, now breed as far south as North Carolina and wander along the Gulf Coast to New Orleans (Forbes 1988). The major species in the Northeast, in ranked abundance are: herring gull, ring-billed gull, and great black-backed gull. The laughing gull is the abundant species in the Southeast.

Ring-billed and California gulls have shown large population increases, including the proliferation of breeding colonies, throughout the western United States (Conover and Conover 1981, Conover 1983). Table 1 summarizes the vital statistics over the last 50 years. Similar increases have taken place in ring-billed gull populations around the Great Lakes region (Ludwig 1974, Blokpoel 1977, Blokpoel and McKeating 1978, Scharf et al. 1978, Blokpoel and Tessier 1984, Forbes 1988). Both of these species breed inland and apparently have prospered from the increased food supply provided by garbage dumps (including their rodent and insect populations) and agricultural crop land (especially grain fields and the associated insect and rodent fauna), as well as an increase in breeding habitat on islands formed by manmade reservoirs (Conover 1983). Colonies of these species, especially the ring-billed, appear to be thriving in the proximity of irrigated agricultural land (Baird 1977, Conover et al. 1979, Conover 1983). The ring-billed gull in the western U.S. feeds more in upland habitats, consuming insects and grain, while the California gull eats more carrion and garbage (Rothweiler 1960, Anderson 1965, Vermeer 1970). These differences in food habits may explain the large increases in the ring-billed populations compared to the California gull in the western United States, paralleling corresponding increases in farming activities (Conover 1983). Decreased predation by man (mainly for eggs and plumage) and other predators may also play a role in the increasing gull populations. Worldwide increases in other gull species have also been documented (reviewed in Conover 1983).

Farmers derive a great deal of benefit from gulls since both the ring-billed and California gulls actively feed on insect and rodent populations in their fields* (Behle 1958, Vermeer 1970). Most food habit studies indicate that throughout their ranges both gulls feed extensively on insects (Greenhalgh 1952, Rothweiler 1960, Anderson 1965, Jarvis and Southern 1976, Haymes and Blokpoel 1978). Garbage was not an important

*The early Mormons erected a monument in Salt Lake City to the California gull for saving their crops during 1848 and 1855 from plagues of long-horned grasshoppers (Anabrus simplex) (Henderson 1933). This is only one of three U.S. monuments commemorating birds; the other two are for an extinct species (passenger pigeon) and an endangered species (Kirtland's warbler) (Terres 1980).

Table 1

Increases in the Number of Colonies and Total Population Sizes of Ring-Billed and California Gulls in Western United States From the 1920s to 1980*

	Ring-Billed Gull		California Gull	
	1920s	1980	1920s	1980
Number of verified colonies	12	57	15	80
Mean number of gulls per colony	397	1867	6734	3455
Estimated total gull population	4800	106,000	101,000	276,000
Percent increase in number of colonies	375%		433%	
Percent increase in total population size	2100%		173%	

*Data calculated from Conover 1983.

in their diet*, even in the two urban studies (Greenhalgh 1952, Haymes and Blokpoel 1978). In Conover's (1983) extensive review of the increasing populations of ring-billed and California gulls he concluded that further increases in their populations should be encouraged, whenever local conditions permit, because they feed on agricultural pests and for their beauty and aesthetic value.

Gulls are often pictured in the context of serene and tranquil settings. However, gulls can be a nuisance in urban settings. The chief complaints about urban ring-billed gulls are the nuisance caused by extensive unsightly and smelly defecation, and their noisy and aggressive behavior when food-begging, stealing, and frightening people (Blokpoel 1983). Their defecation contaminates swimming pools, dining tables, benches, sidewalks, windows, vehicles, food, and water supplies. Gulls have also been implicated in eating the eggs and nestlings of waterfowl (Odin 1957, Vermeer 1970); damaging cherry orchards (Behle 1958), tomatoes, and vegetable shoots; defecating on commercial products; removing insulation from buildings (Blokpoel and Tessier 1984); and causing aircraft collisions (Seubert 1966, Canadian Wildlife Service 1971, Blokpoel 1976). A gull in 1912 caused the first recorded bird strike aircraft accident (McCracken 1976). Currently more than one half of all bird-aircraft strikes worldwide involve gulls (Forbes 1988).

*Garbage may be difficult to consistently identify in crop or gut contents, because of the nature of many of the components.

Canada Geese

Canada geese have been intensely managed in the United States as a highly desirable game species. Over the past decade their populations have dramatically increased, and they have become tame permanent residents of natural as well as man-made impoundments where they graze on short grass and persistently beg for handouts, particularly around picnic areas.

The excrement from the large birds is extensive and causes severe aesthetic and littering problems, potential health hazards, turf damage, and aquatic eutrophication at parks, picnic areas, campgrounds, beaches, athletic fields, golf courses, lawns, and other public-use areas (Hawkins 1970, Laycock 1982, Conover and Chasko 1985). Foraging areas that are consistently used constitute a potential health risk for histoplasmosis (see *Histoplasmosis*, p 39). The littering problem may be of such magnitude that recreational facilities have been abandoned. The Canada goose problem may become more serious in the coming decades. Canada geese and other waterfowl have also been implicated in agricultural damage, primarily to newly sprouting wheat (Bell and Klimstra 1970, Kahl and Samson 1984, Allen et al. 1985, Besser 1985, Flegler et al. 1987).

Swallows

There are eight species of swallows in North America, but only barn and cliff swallows build mud nests which may be closely associated with manmade structures. As in the case of pigeons, the construction of anthropic structures which satisfy the species ecological requirements, particularly nest sites in association with foraging sites, have enabled barn and cliff swallows not only to increase their population sizes but to expand their ranges. Highway bridges crossing streams, rivers, lakes, bays, and reservoirs have been the predominant factor in the success of these two species. This has been particularly dramatic with the spread of cliff swallows (originally a western species) eastward in the last decade (Grant and Quay 1977, Weeks 1984a, personal observation).

Cliff swallows probably come into conflict with man more than barn swallows since the former nest in large colonies. Single colonies of one to two thousand cliff swallows have been reported (Terres 1980). Barn swallows form small colonies or are solitary nesters.

Cliff swallows prefer to attach their gourd-shaped, enclosed nests on overhanging surfaces of cliffs, vertical rock, or concrete or wood surfaces, although rough metal surfaces have been used. The nest has a tubular round entrance near its lower end. Barn swallow nests are open at the top, and flat horizontal surfaces are used in addition to vertical ones. Swallow colonies of these two species, especially large ones, have four requirements for their habitat: (1) an appropriate and large site for nest attachment, (2) mud of the appropriate composition for their nests, (3) fresh drinking water, and (4) an open foraging site with an abundance of insects. Reservoirs and dams represent highly desirable habitats since they fulfill all of these requirements. Extensive areas of open water are ideal since aquatic insect productivity (especially midges) is generally very high.

The mud nests generally cause no problems, and swallows are highly beneficial to man since they consume large quantities of insect pests, including mosquitoes. However, when colonies of cliff swallows are large, there may be aesthetic, safety, corrosion/deterioration, or equipment damage problems caused by excessive excrement. The large numbers of ectoparasites associated with colonial birds may also be a nuisance or health hazard for man.

Woodpeckers

Woodpeckers occasionally are involved in localized damage to wooden buildings or structures such as billboards or telephone poles in suburban or rural settings. Generally, the damage is minor since only one or a few birds are involved. However, in vacant summer cottages their drilling may go undetected and serious damage may occur in siding, eaves, or shutters. Cedar and redwood siding are highly preferred (Marsh 1983). Acorn, Lewis', and red-headed woodpeckers (especially the former) cache stores of acorns and nuts (even insects) in the cracks (natural and drilled) of trees, utility poles, and fence posts. An acorn woodpecker cached 50,000 acorns in a large ponderosa pine (Dawson 1923). In some regions, weakened utility poles must be frequently replaced (Jorgensen et al. 1957). Marsh (1983) predicts that woodpeckers may become involved in new damage problems as more plastic materials, such as rooftop solar panels, are being used for energy-efficient heating and hot-water systems.

Another complaint about woodpeckers is their drumming on houses or utility poles, including the sheet metal on gutters or roofs. Contrary to popular belief, the birds are not usually searching for insects, which they detect by sound, but are communicating with each other. Their drumming is analogous to singing in other bird species and is used by males for advertising territorial claims and attracting females during courtship. Woodpeckers select hollow limbs or other appropriate sites, such as galvanized gutters, as drumming posts to maximize sound resonance or attenuation. This creates a noise problem as well as aesthetic and potential structural damage.

Sapsuckers bore rows of closely spaced holes in the bark of trees and subsequently remove the sap with their tongues. They generally select a few trees to feed from, and their persistence may damage the cambium layer or increase the tree's susceptibility to pathogens or insect pests.

Occasionally woodpeckers cause damage to nut orchards, particularly pecan crops in the Southern states. The acorn woodpecker feeds on walnuts and almonds (Koehler 1962).

Crows, Ravens, Magpies, and Jays

Crows, ravens, magpies, and jays (Corvidae) cause local damage to agricultural crops. All may be scavengers, especially the raven, which often feeds on garbage and at landfills in the arid West.

Crows, magpies, and especially jays cause serious damage to nut crops of pecans, walnuts, almonds, pistachios, and filberts. The American crow prefers English walnuts, while scrub jays prefer almonds (Neff 1937' Birds feed on pecans more heavily than any other commercial nut; about a $10 million loss nationally in an average year (Hall 1984). Crows, blue jays, and woodpeckers are the primary culprits.

Crows may cause serious local damage to sprouting corn seedlings.

Ravens have recently been implicated in contributing to excessive mortality in hatchling and juvenile desert tortoises in the Mojave Desert (Berry 1985, Campbell 1986, U.S. Dept. of Interior 1989). Between the Springs of 1984 and 1988, Peter Woodman (a desert tortoise researcher) found 250 juvenile tortoise carcasses at a single raven nest and perch site (personal communication). Interestingly, only specific nesting pairs of ravens appear to prey heavily on juvenile tortoises (Kristin Berry, personnel communication).

Ravens were very scarce in the Mojave Desert in the 1940's (Johnson et al. 1948). Long-time residents of the Mojave, when questioned about past raven densities, unanimously agreed that the species was scarce, but were of the opinion that turkey vultures were much more abundant than they are today. Apparently, competition for road kills and carcasses has favored the raven, a generalist, opportunistic omnivore with alternative food resources. Between 1968 to 1988 raven populations have increased in the Mojave Desert by 1528 percent (U.S. Department of Interior 1989). This increase in raven populations has paralleled human influx, development, and landuse in the desert. An abundance of food is provided by landfills, garbage dumps, inadequate or careless refuse management, and road kills. Power and communication poles, towers, and associated equipment provide: perches to survey the landscape for prey, resting and roosting sites, and nesting opportunities. Ravens are also preying on birds and their nests, small mammals, lizards, and snakes, but their effects on these taxa are unknown. The impact on the structure and function of the Mojave Desert ecosystem from the large increase in ravens is also undetermined. It may be that the major increases in the raven population are in the vicinity of residential development or expansion, where the majority of environmental deterioration has already occured.

Eagles, Hawks, and Owls

Raptors are highly beneficial since they primarily feed on rodents. The smaller raptors feed heavily on insects when they are abundant. The peregrine falcon is an effective predator of pigeons. Accipiters* and falcons** may consume some game or songbirds, but these species are uncommon and their impact is minimal. Although kestrels (our smallest falcon) are common, they mostly feed on insects, small rodents, and lizards.

Bald eagles eat mainly carrion and fish, although they sometimes feed on waterfowl (usually crippled or sick), other birds, rabbits, squirrels, and muskrats. They occasionally rob ospreys and other hawks of their catches. Ospreys feed almost exclusively on fish, mainly species of low commercial or sport value.

Golden eagles feed primarily on rabbits, marmots, and ground squirrels, but also on small rodents, reptiles, and occasionally birds. They also eat carrion, but not to the same extent as bald eagles. Golden eagles rarely attack healthy large mammals. Much of their reputation as livestock predators can be attributed to carrion feeding, although yearling lambs and kids are occasionally taken.

Owls feed almost exclusively on rodents. The great-horned owl is a large and powerful raptor that possesses an extremely broad diet. Besides rodents it also feeds on rabbits, squirrels, woodchucks, skunks, and has even attacked porcupines. A wide variety of large and small birds--including hawks and owls--reptiles, amphibians, insects, and occasionally scorpions and fish have all been included in their diets. Decapitated bird carcasses generally mean owl predation (Hawthorne 1980). In Pennsylvania, a flock of wild turkeys (16 birds) was found with every individual decapitated but not damaged in any other way, presumably the work of a great-horned owl (personal observation). Great-horned owl predation represents the greatest impediment to the successful establishment of newly released peregrine falcons at some of their historical nesting localities (Barclay and Cade 1983).

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*Accipiters--Goshawk, Cooper's hawk, and Sharp-shinned hawk.
**Falcon--Peregrine falcon (formerly duck hawk), prairie falcon, kestrel, and merlin are common examples.

Bird Roosts

Large flocks of common grackles, red-winged blackbirds, brown-headed cowbirds, and starlings form winter roosts, primarily in southcentral and southeastern United States, which can contain 1 to 10 million or more birds (Webb and Royall 1970, Meanley 1971). Typical species compositions of winter roosts are given in Table 2 (Meanley and Royall 1976). Conflicts with man and these roosting flocks has been extensive and controversial (McAtee 1926, Meanley 1971, Free 1975, U.S. Army 1975, Graham 1976, 1978, Dolbeer et al. 1978). Although all four species are common in winter roosts, the relative

Table 2

Average Species Composition of Winter Blackbird-Starling Roosts, 1974 to 1975*

Species	Eastern States (74%)	Western States (26%)	U.S.A. (100%)
	%	%	%
Red-winged Blackbird	29.7	61.4	37.8
Common Grackle	28.8	1.7	21.9
European Starling	23.4	8.8	19.7
Brown-headed Cowbird	17.9	18.5	18.1
Brewer's Blackbird	trace	7.9	2.0
Tri-colored Blackbird	--	0.8	0.2
Rusty Blackbird	0.2	0.2	0.2
Boat-tailed and Great-tailed Grackles	trace	0.4	0.1
Yellow-headed Blackbird	-	0.2	trace
Bronzed Cowbird	-	trace	trace
	100%	99.9%	100%
TOTALS (millions)			
Above Species	372.77	128.66	501.43
Other Species	25.66 (6.4%)	10.73 (7.7%)	36.39 (6.8%)
Sum	398.43	139.39	537.82

*Data calculated from Meanley and Royale 1976.

abundance of each species is variable. Grackles are usually the most abundant species, especially in Tennessee and Kentucky, but starlings or cowbirds may be the dominant species (Don Mott, personal communication). In a detailed study of a major winter roost in southwestern Tennessee over a three-year period, common grackles comprised 68 to 80 percent of the population, red-wings 10 to 20 percent, starlings usually less than 10 percent, and brown-headed cowbirds about 1 to 2 percent (White et al. 1985).

These roosts are responsible for two major problems in addition to the obvious aesthetic impacts of excessive bird waste, noise, and habitat damage. Serious depredations to agricultural grain crops and livestock feedlots have been reported near large roosts, and winter roosts have been implicated in harboring *Histoplasma capsulatum*, the fungus that causes histoplasmosis, a respiratory infection in man and other mammals. Table 3 provides a summary of the winter diet of a typical roost.

The flocks select rather specific roosting sites possessing dense canopy stands of immature trees (Lyon and Caccamise 1981, Micacchion and Townsend 1983). Such an environment provides an optimal microclimate for winter roosts with regard to air temperature and circulation, wind velocity, and the radiant environment (Francis 1976,

Table 3

Percent Composition of the Winter (November to March) Diet of a Large Blackbird Roost in Tennessee, 1976 to 1978*

Food Item	Grackles (70-80%)[A] N=677[B]	Red-Winged Blackbirds (10-20%) N=149	Starlings < 10% N=58	Cowbirds < 2% N=10
Corn	54	30	28	22
Wheat	0	< 1	4	0
Sorghum	0	1	0	0
Weed Seeds	6	62	22	74
Tree Seeds (mostly acorns)	26	0	7	0
Insects	14	5	33	4
Misc. Items	< 1	1	6	0

*Data calculated from White et al. 1985.
A - Composition of the Roosting Population
B - Sample Size for Food Habits

Kelty and Lustick 1977, Yom-Tov et al. 1977, Lustick 1981). This environment minimizes radiative and convective heat loss by the birds, a critical condition during the winter for small animals (high surface to volume ratio) possessing a high body temperature. The use of mature trees for roosting sites have also been reported (Bliese 1953, Jumber 1956, Good and Johnson 1978). A variety of forest communities and tree species have provided the appropriate physiognomy (vegetation structural characteristics): live oaks (evergreen) (Good and Johnson 1976, 1978); maples (Bliese 1953); Norway maple and sycamore (Jumber 1956); elm, green ash, and silver maple mixed deciduous lowland communities (Micacchion and Townsend 1983); red maple-sweetgum communities (Lyon 1979, Lyon and Caccamise 1981); loblolly pine (Francis 1976); white pine (Kelty and Lustick 1977, Lustick 1981). At many localities in the northern United States, roosts can be found in spruce groves (usually Norway spruce), pine plantations (red, white, Austrian, and Scotch pines), and occasionally in cattail (*Typha* spp.) or reed (*Phragmites communis*) marshes (personal observation). Lyon and Caccamise (1981) reported that 2 of the 25 communal roosts found were in red marshes.

Agriculture

Bird damage to agricultural crops in the United States costs growers more than $100 million annually (Besser 1985). Local damage to ripening corn by blackbirds has been well documented (Cardinell and Hayne 1945, Linehan 1967, Stone et al. 1972, Stone and Mott 1973a, DeHaven 1974a, Stickley et al. 1979, Tyler and Kannenberg 1980, Wakeley and Mitchell 1981). Blackbirds also damage sprouting corn (Stone and Mott 1973b) and mature corn (Stickley et al. 1978). Blackbird (red-wing and grackle) depredation on field corn was estimated at $34.8 million in 1981 (Kelly and Dolbeer 1984), and Besser and DeGrazio (1985) reported that this is the number one agricultural bird damage problem in the United States. Blackbird damage to corn and sunflowers in Manitoba, Canada during 1983 was just under $2 million (Harris 1983).

Local damage by blackbirds to sprouting and ripening rice has been reported (Kalmbach 1937a, Pierce 1970, Besser 1973, Holler et al. 1982, 1985). Blackbirds have been implicated in depredating ripening sunflower crops (Stone 1973, Besser and Guarino 1976, Harris 1983, Guarino and Cummings 1985, Cummings et al. 1989). Red-winged blackbirds are the primary species depredating sunflower crops in North Dakota, South Dakota, and Minnesota, the three most important sunflower producing states, but common grackles and yellow-headed blackbirds are also included (Hothem et al. 1988). Damages to sunflower crops may be particularly severe, since red-winged blackbirds are able to extract sunflower seeds easier than corn kernels (Linz and Fox 1983). The estimated losses of the sunflower crop to blackbirds in these three states has been estimated at $5 to $8 million annually in 1979 and 1980 (Hothem et al. 1988). Damage to sunflower crops is not uniformly distributed. Otis and Kilburn (1988) associated six habitat factors with sunflower fields that received heavy damage by blackbirds. The largest influence on damage levels was the presence of nearby marshes. Blackbirds have also been implicated in serious depredations on sweet corn and grain sorghum. Starlings may feed extensively on sprouting wheat. Although blackbirds and starlings are the major source of agricultural bird damage in the United States, game birds have also been implicated. Pheasants feed on sprouting corn and Canada geese and ducks on sprouting wheat.

Birds are also responsible for serious damage to fruit crops (Guarino 1975, Clark 1976, Crase et al. 1976). Crase et al. (1976) reported that bird damage to grapes in the United States was at least $4.4 million in 1972, with the California loss representing over $3.7 million. The birds responsible in California were the house finch and starling

(DeHaven 1974b, Crase et al. 1976). Along the southern Lake Erie shore in Ohio, 28.3 percent of the diet of summer-fall starlings consisted of grapes (Williams 1976). Additionally, sparrows, robins, bluebirds, waxwings, and 23 other species have been reported to damage grapes (Besser 1985). Conover (1982) reported that about 50 percent of the total blueberry crop was destroyed each week in Connecticut farms when left unprotected. The primary culprits were starlings, blue jays, mockingbirds, robins, northern orioles, and brown thrashers. Mott and Stone (1973) reported that starlings, robins, and grackles cause the most damage to highbush and lowbush blueberries. Besser (1985) lists an additional 16 species that feed on highbush blueberries. Blueberries have been found in the stomach of at least 93 species of United States birds (McAtee 1942). Cherries are also severely impacted by bird depredations (Guarino et al., 1973, 1974, Stickley and Ingram 1973). Sweet cherries are damaged more than tart cherries because of their longer period of vulnerability and their higher sugar content. Starlings, robins, orioles, and house finches are the primary culprits that damage cherries, but grosbeaks, catbirds, waxwings, grackles, blue jays, and woodpeckers are also involved (Besser 1985). Great-tailed grackles have been implicated in damaging grapefruit in southern Texas (Johnson et al. 1989).

Clark (1976) lists 23 species of birds, including 2 exotics (monk parakeet and red-whiskered bulbul) as creating nuisance bird problems in California--mainly agricultural damage. For over a century the house finch and horned lark were implicated as the severest pests to California crops. The house finch feeds on the buds of fruit and nut trees, embryonic and mature fruits and nuts, small grains, and vegetable and flower seeds. The primary damage by horned larks is on newly planted seeds and sprouts/seedlings of vegetable and flower crops. This very common western bird is a species of open habitats, preferring to forage on bare ground, and occurs in large flocks during the nonbreeding season (personal observation). Therefore, it possesses a high potential to damage newly planted or sprouting crops. Winter flocks of white-crowned, golden-crowned, and other sparrows also commonly feed on the early sprouting seeds of a variety of western crops. American and lesser goldfinches remove strawberry seeds, causing decay of the fruit. These species also remove mature seeds from flower and vegetable crops produced by commercial seed growers. Acorn and Lewis' woodpeckers and flockers have been involved in damaging almond and apple trees. Jays, crows, and magpies cause serious damage to nut orchards (see *Crows, Ravens, Magpies, and Jays*, p 20).

Because of the high population levels at fall and winter roosts, roosting birds have generally been blamed for extensive agricultural losses during the fall and early spring, particularly in the southern states. Louisiana, Mississippi, and Arkansas harbored 43 percent of the 137 major roosts of a million or more birds in the United States (Meanley and Royall 1976). Although local damage to grain crops may occasionally be severe at farms located near major blackbird-starling roosts (Dyer 1967, Martin 1977, Dolbeer 1980, Mott 1984), studies initiated in Kentucky and Tennessee to evaluate the effects of roosting flocks on sprouting and ripening corn and sprouting wheat concluded that the total bird damage to these resources was minor compared to damage from insects or weather. Williams (1976) reported that only 0.27 percent of the corn yield for three Ohio counties was consumed by roosting birds (primarily red-winged blackbirds) during the summer-fall flocking season. Dolbeer (1981) and Mott (1984) concluded that overall agricultural losses around the country are generally less than 1 percent of the total crop. These losses are negligible contrasted to damages caused by insects, other pathogens, and the weather. Jugenheimer (1976), Pimentel (1976), and McEwen (1978) estimated that for Midwestern corn the combined losses caused by insects, disease, fungi, and weeds was greater than 20 percent of the total harvest and an additional 5 percent of the potential harvest remained on the field as crop residue (Jugenheimer 1976). White et

al. (1985) similarly concluded from a detailed study of a major blackbird-starling roost in Tennessee that the overall agricultural impact was negligible since most of the corn consumed came from fields already harvested. Interestingly, corn damage in western Ohio did not correlate with the relative population sizes of breeding red-winged blackbirds over a 9-year period (Stehn and deBecker 1982). Dyer (1975, 1976) found that bird damage to maturing corn *increased* the yield in some cases.

Feedlots

Blackbirds, but particularly starlings, have been implicated in economic losses at cattle and swine feedlots and dairy and chicken farms (Bailey 1966, Besser et al. 1967, 1968, Feare 1975, 1980, Palmer 1976, Stickley 1979, Twedt and Glahn 1982, Glahn 1983, Mason et al. 1985). In a recent survey of Kansas feedlots, 49 percent of bird depredation complaints identified starlings, 21 percent house sparrows, 20 percent blackbirds, and 11 percent pigeons (data from Lee 1988). The main problem was the consumption or spoiling of livestock feed, but the birds may be vectors in the spread of livestock disease (Gough and Beyer 1982), especially TGE (transmissible gastro-enteritis, baby pig disease) (Gough et al. 1979). Hobson and Geuder (1976) surveyed 2051 randomly selected farmers in Tennessee and reported a loss of $4.2 million from consumed or spoiled feed. In a randomly selected sample of 287 Tennessee dairy, beef, and swine feedlots, Glahn (1983) concluded that 25.8 percent had more than negligible problems, including 6.3 percent with significant damage. Lee (1988) reported that 64 percent of Kansas feedlots surveyed cited feed loss as their major problem. When complete diets were fed to dairy cows in open troughs, birds selectively removed up to 97 percent of the high protein components of the ration (Feare and Wadsworth 1981).

White et al. (1985), in a detailed study of the feeding ecology of a large (> [illegible] million birds) Tennessee winter roost of blackbirds and starlings, found that the overall losses of corn at all feedlots in the foraging range of the roost were about 1 percent (0.2[illegible] percent in swine feedlots). However, a few scattered feedlots received significant losses in midwinter after snowfalls, when grackles foraged in large numbers. Although cowbirds foraged almost exclusively in feedlots, they primarily consumed weed seeds (74 percent of diet). Starlings used feedlots frequently and accounted for 75 percent of all birds in swine feedlots. This was the species most frequently observed in the feed troughs. Grackles only came into feedlots during severe winter weather when snow cover exceeded 2.5 cm. Red-winged blackbirds were uncommon in feedlots.

Safety Hazards

Research and reports dealing with the safety hazards associated with birds have generally been limited to aircraft collisions (Seubert 1966, Canadian Wildlife Service 1971, Blokpoel 1976, Harrison 1976, McCracken 1976, Solman 1976, Terres 1980, Walker and Bennett 1985). Probably the most dramatic case was the 1960 collision of an Electra turboprop with a large flock of starlings at Boston's Logan Airport when 62 people were killed. The birds were sucked into three of the four engines continuously for several seconds during the critical takeoff period. In the United States about 200 people have been killed in bird-strike accidents (Murton and Westwood 1976). The annual cost to repair aircraft damage resulting from bird-strikes exceeds $1 billion worldwide and $10 million in the United States (Lefebvre and Mott 1983).

Aircraft collisions with birds occur at a rate of one to three collisions per 10,000 takeoffs and landings, generally without damage to the aircraft (Terres 1980). Fully 75 percent of all bird-strikes occur at or near airports (Solman 1971). During 1984 there

were 331 bird-strikes with naval aircraft for every 100,000 hours of flight time (Walker and Bennett 1985).

Gulls are the number one aircraft bird hazards in eastern North America. They are involved in half of all bird-aircraft strikes in Canada (Blokpoel 1976) and worldwide (Forbes 1988).

The Air Force has developed an extensive awareness and research and development program to directly assist military bases in reducing bird-aircraft collisions (Will 1983). The BASH (Bird-Aircraft Strike Hazard) Team has been dealing with the problem for over a decade, and Air Force bird-strike rates have gradually decreased as the program has progressed (Kull 1983). Four naval air stations implementing BASH procedures in 1984 reported 57 to 78 percent fewer collisions with birds than in 1983 (Walker and Bennett 1985).

Other safety hazards, such as equipment failure or the fall of a worker from scaffolding, ladders, or walkways because of slippery bird excrement or being startled by a flushed or attacking bird, have not been researched.

4 BIRDS AS POTENTIAL DISEASE VECTORS

Birds possess an unusually large number and wide variety of external and internal parasites, and are subjected to a wide variety of viral, bacterial, fungal, and protozoan infections. Most avian pathogens are exclusively or primarily confined to birds. Wild and domestic bird populations have often infected one another in large epidemics, often with serious economic consequences. These have included: poultry, pigeons, waterfowl, game and nongame species, valuable pets, and aviary and zoo specimens. Mammals (e.g., domestic pets, livestock, and rodents) are a much greater threat to human health than birds. Birds are responsible for relatively few health or disease hazards, many being rare or mild. In this section, 5 major and 15 minor or potential health hazards are discussed. There is a very small potential that other pathogens may be transmitted by birds. For example, anthrax and brucellosis are mainly confined to livestock, leptospirosis primarily infects rodents, and botulism is commonly fatal to large flocks of waterfowl. Although humans have contracted these infections, avian sources have never been implicated in their transmission to humans. Avian pox and avian malaria have never been reported in humans.

Internal parasites include: cestodes (tapeworms), trematodes (flukes), and nematodes (ascariasis and trichinosis). Since internal parasites are highly host specific, avian infections are unlikely to be transmitted to humans or other mammals. External parasites also exhibit host specificity, but not to the same degree as internal parasites. Avian parasites are not considered a threat to human health (Grimes 1987).

Most bird species are territorial and mated pairs, individuals, or family groups defend conspecific territories* of fixed size, usually during the breeding season. These species are widely spaced; therefore minimizing the spread of contagious infections. On the other hand, social or colonial species live in close proximity at high population densities, greatly facilitating the spread of diseases among themselves, and increasing the probability of transmission to domestic or wild animals. Birds that possess the greatest opportunities to transmit pathogens to humans are species that are highly social and also associated with humans. Three species--common pigeon, English starling, and house sparrow--meet both criteria and all three have been implicated with transmitting diseases to humans. Table 4 is a summary of infections occurring in humans and domestic animals that are also associated with pigeons, starlings, and house sparrows (mainly from Weber 1979).

Major Health Problems Associated With Birds

Chlamydiosis

The average person is probably more familiar with parrot fever than with any other disease associated with birds. Parrot fever is the vernacular for psittacosis, also called ornithosis. Page (1966, 1963) has suggested the name chlamydiosis to clarify the

*Territories are generally defended against members of the same species. Territory sizes vary with species, site specific habitat quality, and food abundance. Robins defend small territories (400 to 2500 sq m), while golden eagles possess large territories (50 to 160 sq km). Most songbirds usually have territory sizes of 0.3 to 3 hectares.

Table 4

Bird-Associated Infections Occurring in Humans and Domestic Animals

	Carrier													
	Pigeons	Starlings	House Sparrows	Humans	Cattle	Swine	Horses	Sheep	Chickens	Turkeys	Ducks	Geese	Dogs	Cats
<u>Viruses</u>														
Eastern Equine Encephalitis	x	x	x	*			*			*	*			
St. Louis Encephalitis	x	x	x	*										
Western Equine Encephalitis	x		x	*			*		*	*				
Meningitis	x			+	+	+		+	+	+			+	+
Newcastle Disease	x	x	x	+					*	*	*			
Avian Pox	x	x	x						*	*				
Transmissible Gastroenteritis		x	x			*								
<u>Bacteria</u>														
Chlamydiosis (*Chlamydia psittaci*)	x	x	x	*	+	+	+	*	*	*	*	+	+	+
Erysipeloid (*Erysipelothrix insidiosa*)	x	x	x	*	+	*	+	+	*	*	*			
Fowl typhoid (*Salmonella gallinarum*)	x								*	*	*			
Infectious Coryza (*Haemophilus gallinarum*)	x								*					

x = carrier of indicated disease
* = the infection is serious and may result in death
+ = the infection is usually not serious or fatal

Table 4 (Cont'd)

	Carriers: Pigeons	Carriers: Starlings	Carriers: House Sparrows	Humans	Cattle	Swine	Horses	Sheep	Chickens	Turkeys	Ducks	Geese	Dogs	Cats
<u>Bacteria</u> (Cont'd)														
Listeriosis (*Listeria monocytogenes*)	x		x	+	+	+	+	+	*		+	*	+	+
Paratyphoid (*Salmonella typhimurium*)	x	x	x	+	+	+	+	+	+	+	+	+	+	+
Pasteurellosis (Fowl cholera) (*Pasteurella multocida*)	x	x		+	+	+	+		*	*	*	*	+	+
Pullorum Disease (*Salmonella pullorum*)	x		x	+					*	*				
Q Fever (*Rickettsia burneti*)	x	x		*	+			+						
Salmonellosis (*Salmonella* sp.)	x	x	x	*	*	*	+	*	*	*	*	*	+	+
Spirochetosis (*Borrelia anserina*)	x	x	x						*		*			
Streptococcosis (*Streptococcus zooepidemicus*)	x				+	*	+	+	*	*	*			
Tuberculosis (avian) (*Mycobacterium avium*)	x	x	x	+	+	*	+	+	*	*			+	+
Ulcerative enteritis (*Clostridium colinum*)	x								*	*				
Vibriosis (*Vibrio fetus*)			x	*	*			*						

Table 4 (Cont'd)

	Carriers													
	Pigeons	Starlings	House Sparrows	Humans	Cattle	Swine	Horses	Sheep	Chickens	Turkeys	Ducks	Geese	Dogs	Cats
<u>Bacteria</u> (Cont'd)														
Yersiniosis (*Yersinia pseudo-tuberculosis and Y. enterocolitica*)	x	x	x	*	+		+	+	*	*	*		+	*
<u>Fungi</u>														
Aspergillosis (*Aspergillus fumigatus*)	x			+	+				*	*	*			
Blastomycosis (*Blastomyces dermatitidis*)	x	x		+			+						+	+
Candidiasis (*Candida albicans*)	x			*	+	+	+	+	*	*		+	+	+
Cryptococcosis (*Cryptococcus neoformans*)	x			*	+	+	+						+	+
Histoplasmosis (*Histoplasma capsulatum*)	x	x		*	+	+	+						*	+
<u>Protozoans</u>														
Coccidiosis (*Eimeria* sp. and others)	x	x	x		+			+	*	+				
Haemoproteus	x								*	*	*	*		
Leucocytozoonosis (*Leucocytozoon*)	x										*	*		
Sarcosporidiasis			x	+	+	+	+	+	+		+			
Toxoplasmosis (*Toxoplasma gondii*)	x	x	x	*	*	*	+	*	*	*			*	+

Table 4 (Cont'd)

	Carriers													
	Pigeons	Starlings	House Sparrows	Humans	Cattle	Swine	Horses	Sheep	Chickens	Turkeys	Ducks	Geese	Dogs	Cats
<u>Protozoans</u> (Cont'd)														
Trichomoniasis (*Trichomonas gallinae*)	x		x	+	+			+	*	*	+			
Trypanosomiasis (American) (Chagas' Disease) (*Trypanosoma cruzi*)	x			*		+							+	+
<u>Cestodes</u> (Tapeworms)														
Davinea proglottina	x								+					
Railletina tetragona	x								+					
Taenia saginata (Beef tapeworm)	x	x	x	+	+									
<u>Nematodes</u> (Roundworms)														
Capillariasis (*Capillaria* sp.)	x	x		+					+	+	+			
Dispharynxiasis (*Dispharynx nasuta*)	x	x	x						*	*				
Eyeworm (*Oxyspirura mansoni*)	x								+					
Gapeworm (*Syngamus trcchea*)		x							*	*				
Tetrameriasis (*Tetrameres americana* or *T. fissipina*)	x	x	x						*	*	*			
<u>Trematodes</u> (Flukes)														
Schistosomiasis (many species)	x	x	x	+	+	+	+	+					+	+

Table 4 (Cont'd)

	Carriers													
	Pigeons	Starlings	House Sparrows	Humans	Cattle	Swine	Horses	Sheep	Chickens	Turkeys	Ducks	Geese	Dogs	Cats
Trematodes (Cont'd)														
Brachylaemus commutatus	x								+	+				
Brachylaemus fuscatus	x		x						+		+			
Collyriclum faba		x	x						*	*				
Cotylurus cornutus	x										+			
Cryptocoyle convacuum	x								+	+	+		+	
Echinoparyphium recurvatum	x			+					+	+	+			
Echinostoma revolutum	x			+					+	+	+	+		
Haplorchis pumilio	x			+					+				+	+
Hypoderaeum conoideum	x			+					+		+	+		
Plagiorchis murus	x			+				+					+	
Postharmostomum gallinium	x								+	+				
Riberioia ondatrae	x								+			+		
Tamerlania bragai	x								+	+				

terminology, since psittacosis implies that psittacine* birds are the primary disease transmitters. In actuality, over 140 bird species in 17 orders have been implicated (Burkhart and Page 1971, Campbell and Lack 1985). The birds most frequently infected with chlamydiosis, in relative order, are: pigeons (feral and domestic), psittacines, domestic fowl (turkeys, geese, and ducks), waterfowl, wading birds, and gulls (Locke 1987a), but the disease appears in domestic and wild birds and mammals throughout the world. It has been reported in starlings and house sparrows. The most common and consistent source of infections are feral pigeons (Burkhart and Page 1971, Weber 1979). Two-thirds of the pigeons in Paris were estimated to be infected with chlamydiosis (Welty 1979). In a 1944 Chicago epidemic of the disease in humans, 45 percent of the pigeons in the city were estimated to be infected (Welty 1979). When 16,500 pigeons were examined by 50 researchers in 24 countries, 27 percent tested positive for chlamydiosis (Weber 1979). Other examples of the infection rate in sampled pigeon populations are: Birmingham, Alabama--60 percent; Washington D.C.--35 percent; Ontario, Canada--16 percent; Baltimore, Maryland--15 percent; and 73 percent (27 of 37 pigeons) at an isolated Oregon cattle ranch (Weber 1979).

Chlamydiosis is caused by the bacteria *Chlamydia psittaci*. Many strains have been isolated, and pathological effects on bird populations vary from mild infections to complete mortality (Arnstein et al. 1982). Most field isolates exhibit pathogenicity between these two extremes. Additionally, the various strains affect different bird species differently. In disease-free flocks, a new infection may cause 90 percent mortality in all age classes, while in flocks where the disease is enzootic, the mortality rate is usually between 10 and 20 percent, with young birds being most susceptible (Arnstein et al. 1982). Most chlamydial strains isolated from pigeons are not usually virulent for either pigeons or humans, but there are exceptions. Other birds that usually exhibit mild infections, at least for some strains, are: chickens, turkeys, gulls, and some psittacines (e.g., Australian cockatoos). Most bird species, including neotropical psittacines, are very susceptible and mortality approaches 100 percent without treatment. Bird species that are characterized by mild or asymptomatic (absence of symptoms) infections (e. g., pigeons and some psittacines) are reservoirs for the disease. Once infected, birds probably remain unapparent carriers. Immunity or resistance to clinical symptoms may depend on a persistent low level infection (Schachter 1975). Since mortality is high in native species, wild birds have low infection potential (Arnstein et al. 1968). Worth et al. (1957) concluded that native North American bird species neither constitute a health hazard for humans nor are they a significant reservoir for the bacteria.

Human *Chlamydia* infections usually resemble pneumonia or flu, and occasionally respiratory symptoms are absent. The disease may be accompanied by fever, chills, headaches, loss of appetite, vomiting, diarrhea, or muscle pains. Symptoms vary from subclinical to severe pneumonia with septicemia (blood poisoning). Human mortality is low, and treatment is very effective. Mortality is usually restricted to the old or those incapacitated with other diseases. However, virulent strains have caused death rates of up to 20 percent (Weber 1979). About 150 cases are reported annually in the United States (U.S. Army 1985). Chlamydiosis is treated in both humans and birds with tetracyclines, especially chlortetracycline (Arnstein et al. 1982).

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*The order Psittaciformes is comprised of only a single family, Psittacidae, and seven subfamilies: true parrots (parrots, parakeets, lovebirds, macaws, etc.), keas, vulturine parrots, cockatoos, pygmy parrots, lories, and owl parrots (79 genera, 326 species) (Grzimek 1975).

Infected birds need not show symptoms, but can still transmit the disease (Schachter and Dawson 1978). Feces and feathers are prime sources for the bacteria. *Chlamydia* is very stable in the dry state, making it available as infective aerosols (Schachter 1975). The bacteria can be transmitted to man by airborne inhalation, inadvertent ingestion of infected bird excrement or nasal discharges, skin-piercing bites by infected birds, or possibly by arthropod vectors. Arthropod vectors have not been shown to be true chlamydial vectors (Schachter 1975), but they may be mechanical vectors (Digregorio and Johnson 1937). *Chlamydia* has been recovered from ticks and fleas (Eddie et al. 1969) and from mites (Eddie et al. 1962). Birds could become infected by ingesting these arthropods. Ticks or fleas could transmit *Chlamydia* to mammalian hosts. Human to human transmission of chlamydiosis is rare, but has been documented (Schachter 1975, Bruu et al. 1984, Nagington 1984).

The disease is most prevalent among breeders of pigeons or poultry, and workers processing poultry (Boyd 1958, Meyer 1965). Bird-banders, wildlife specialists, and aviary workers are often exposed to infected birds and contract the disease (Wobeser and Brand 1982).

Salmonellosis

Salmonellosis is caused by bacteria of the genus *Salmonella*, with about 2000 identified serotypes. However, *S. typhimurium* and *S. enteritidis* are the two most frequently identified with human clinical cases (Williams and Hobbs 1975). *S. typhimurium* is also the most common form found in birds (Stroud and Friend 1987). *Salmonella* serotypes are widely distributed throughout vertebrate species (pets, domestic and wild animals). Only a few serotypes have shown high host specificity. Children are frequently exposed to potential *Salmonella* infections from pets, especially dogs (Willard et al. 1987) and turtles (Stehr-Green and Schantz 1987).

Salmonella infections vary from asymptomatic (lack of symptoms), mild discomfort, severe gastroenteritis (food poisoning), septicemia, or serious organ infections. Mild infections occur in over 2 million people in the United States, and the Center for Disease Control reported 23,445 *Salmonella* isolations in 1975 (Weber 1979). Symptoms of food poisoning occur within 8 to 48 hr after ingesting a sufficient infectious dose of bacteria and may last for several days to a week. Symptoms include: nausea and vomiting, fever, chills, diarrhea, headache, and abdominal pains. Although not usually fatal, Salmonellosis is usually more severe and mortality is higher in infants, infirmed, and old people. In severe cases, inflammations in joints, bones, heart lining, or brain membranes may occur.

The usual mode of transmission is eating infected food. Poultry products are a common source of infection. *Salmonella* multiplies rapidly above 24 °C. Refrigeration, even freezing, does not kill *Salmonella* but inhibits growth so that an infective dose is not reached. Direct sunlight or 2 1/2 minutes at 64 °C will kill the organism.

Salmonella infections are most common and widespread among wild, captive, and domestic birds (Fiennes 1982). *Salmonella* infections are most common in domestic turkeys, but also occur in domestic chickens and waterfowl, canaries, parrots, parakeets and pigeons (Stroud and Friend 1987). In wild birds, *Salmonella* frequently occurs in waterfowl, gulls, passerines (songbirds), and upland game birds (Jungherr 1940, Kirkpatrik 1988, Stroud and Friend 1987). Weber (1979) surmises that pigeons and house sparrows are important carriers of *Salmonella*. *Salmonella* can be found in bird droppings and carried airborne in dried feces. Dried bird droppings on ledges or roofs near air-conditioning systems or air-vents are a potential source of infection.

Encephalitis

Blood-feeding arthropods (e.g., insects, ticks, and mites) represent disease vectors that possess the potential to spread viral, bacterial, protozoan, and nematode infections among vertebrates. Despite the large variety and number of blood-suckers that feed on adult and nestling birds, they are not usually considered as being serious threats to human health. The exception is arbovirus induced encephalitis carried by certain mosquito species using birds as reservoir hosts and humans as incidental hosts. An arbovirus is a virus found in the blood stream of infected vertebrates and is spread among other vertebrates by blood-feeding arthropods. A typical encephalitis epidemic has the following pattern. An infected mosquito feeding on a bird's blood infects the bird. The virus rapidly multiplies in the bird, and other mosquitoes feeding on the bird are infected. These mosquitoes then infect other birds. A large number of birds, each with sufficient viremia (virus in the bloodstream), constitute the arbovirus reservoir which infects specific mosquito vectors. The mosquitoes transmit the virus through salivary glands to human hosts. One strain of arbovirus (SLE) has been shown to multiply a millionfold in an individual mosquito, *Culex tarsalis* (Herms and James 1961). Epidemic outbreaks in human populations are self-limiting, being controlled by the natural decline of mosquito vector populations and the development of immunity in the bird reservoir population.

Humans are not known to become infected directly from birds. However, the possibility exists that mites (e.g., *Ornithonyssus* sp., *Dermanyssus gallinae*) may spread arboviruses among bird populations. Encephalitis arbovirus (WEE) has been isolated from *O. bursa* (Weber 1979). The virus can survive in dried blood for two or more weeks and may be transmitted among domestic flock members through peck wounds (Horsfall 1962). Occasional direct infection of humans has resulted from inhalation of airborne particles of lyophilized (freeze-dried lab specimens) virus during breakage of ampoules or by injection of infected material (McLean 1975).

Encephalitis antibodies, viremia, and severe infections have been reported in many species of mammals, birds, and reptiles (Johnson 1960, Karstad 1961, Rehacek et al. 1961, Hayes et al. 1964, Spalatin et al. 1964). Species with low-grade viremia (e.g., humans, horses, and some birds) apparently cannot infect mosquitoes and therefore cannot be reservoirs (Herman 1982). Some species of birds and other vertebrates sustain prolonged periods of high viremia, making them arbovirus reservoirs. Infection potential, its severity, and viremia vary considerably among hosts and mosquito species. Successful transmission of the arbovirus from mosquito to host is also highly variable and vector species dependent (Herms and James 1961). Even populations of a given mosquito species show considerable intraspecific variation in their ability to transmit arboviruses (e.g., *Culex tarsalis* and WEE) (Reeves 1982). Several instances of viral transmission through eggs to larval mosquitos (transovarial) have been reported (Reeves 1982).

Only a small percentage of people infected with encephalitis arbovirus actually develop clinical symptoms (Kettle 1984), antibodies successfully repel the invading virus. Symptoms in mild cases include: fever, headaches, neck pains, nausea and vomiting. In severe cases, there is inflammation of central nervous system membranes, especially in the brain, that causes drowsiness and impedes mental and physical processes. Coma, death, or permanent damage to the nervous system often result from severe cases. Survivors may experience mental retardation, convulsions, or paralysis. Encephalitis may be particularly severe in sick or infirmed individuals.

There are five major encephalitis arboviruses that infect humans in the United States: eastern equine encephalitis (EEE), western equine encephalitis (WEE), St. Louis

encephalitis (SLE), LaCrosse encephalitis (LAC), and Californis encephalitis (CAL) (Hubbert et al. 1975, Gordon 1983). The usual hosts for the first three arboviruses are wild birds, while the latter two strains primarily infect rodents, generally squirrels, ground squirrels, and chipmunks. EEE and WEE are Type A arboviruses and the forms best known (Kissling 1965, Karstad 1971). Both of these also cause serious cases of encephalomyelitis in horses. Other encephalitis arborviruses have been reported from the United States and all continents, particularly in tropical regions.

Gordon (1983) has summarized the extent of encephalitis infections in the United States for the calendar year 1983 (as of 4 November). EEE infected 120 horses and 12 humans, with 3 human fatalities. WEE infected 101 horses and 13 humans, with 1 human fatality (6 cases occurred just across the border in Manitoba, Canada). SLE infected 10 humans.

EEE occurs mainly along the Atlantic and Gulf coasts from Massachusetts to Texas, but has been reported from many other localities in the United States, eastern Canada, Caribbean, and Central and South America. This strain is the most serious North American arbovirus on the basis of mortality and morbidity rates, but it is not contracted as often by humans as SLE and WEE (Herms and James 1961). It appears with a higher frequency in children. Reported death rates for children less than 10 years old have been 65 to 70 percent (Fiennes 1978) and 60 percent (Weber 1979). Human epidemics in Massachusetts resulted in 25 deaths in 34 cases in 1938, and 10 deaths in 13 cases in 1956 (Herms and James 1961). An average of 5.7 cases were reported annually in the United States between 1955 and 1978 (Monath 1979). Horses are more commonly afflicted than humans with an average of 40 reported cases annually from 1956 to 1972 (Monath 1979). Death rates in horses may often reach 90 percent (Fiennes 1982). EEE has caused severe mortality in ring-necked pheasants at commercial farms in Atlantic coastal states (Beadle 1952, Stamm 1958, Monath 1979). EEE also causes mortality in wild bird populations (Stamm 1958, Williams et al. 1971).

Culiseta melanura, a bird feeder, is the primary endemic vector of EEE in North America (Reeves et al. 1958, Howard and Wallis 1974). This species breeds in freshwater swamps from the Gulf of Mexico to Canada. However, *C. melanura* rarely bites humans. *Aedes sollicitans* and *A. vexans*, particularly the former, are probably the primary vectors infecting humans with EEE (McLean 1975). Most human and equine infections, and epizootics in exotic game birds, have resulted from occasional movements of the virus from enzootic foci in swamps and not from exposure within a swamp (McLean et al. 1985). It has not been established if the movement of EEE virus out of its foci is due primarily to infection of other mosquito species or to viremic birds. Natural and experimental infections of EEE have been reported in 51 species of wild birds (Herman 1962, Stamm 1963). Pigeons and starlings may be important reservoirs for EEE (Weber 1979). Reptiles have been suspected as reservoir hosts (Karstad 1961, Craighead et al. 1962, Hayes et al. 1964, and nonavian vertebrates have been implicated in some instances (Hayes et al. 1962, Wallis and Main 1974).

A field study in Michigan for EEE hosts showed that 29.9 percent of 42 species of free-living birds (N=401) examined carried EEE antibodies, while no viruses or antibodies were found in 6 species of native small mammals (N=17) and sentinel rabbits (N=11) (McLean et al. 1985). EEE antibodies were developed by 11.4 percent of captive birds (N=220) used as sentinels (mostly ring-necked pheasants and chickens). Avian species associated with swamp habitats in this area (bluejay, black-capped chickadee, tufted titmouse, wood thrush, and catbird) carried EEE antibodies at a rate of 81.8 percent. The EEE antibody rate was 29.1 percent (N=302) for birds that were permanent residents, 36.3 percent (N=76) for summer residents, and 17.4 percent (N=23) for transient species.

However, the only transient species to carry antibodies was Swainson's thrush (4 of 11 individuals). The authors concluded that birds in the swamp habitats were the reservoir hosts for EEE, and bird species associated with agricultural and urban areas acquired their infections from swamp foci.

WEE has primarily been recorded from west of the Mississippi River, Illinois, and Wisconsin, although its prevalence througFout the eastern United States has increased steadily (McLean 1975). WEE is generally considered the least virulent of the three avian reservoir arbovirus strains (see SLE for discussion). The largest human epidemic occurred in North Dakota, Minnesota, and adjacent Canada in 1941. There were over 3000 cases with a mortality of 8 to 15 percent (Horsfall 1962). Children are affected more than adults in both frequency and severity. Children less than one year of age suffer permanent neurological damage (Weber 1979). Horses are also highly susceptible, suffering a mortality of 27 percent (Fiennes 1978).

The prominent mosquito vector for WEE in the western and central United States is *Culex tarsalis*, which feeds on both mammals and birds and readily invades houses (Matheson 1944, Hess and Holden 1958). This is a widespread species, abundant in the semiarid regions of western North America, and also found in North and South Dakota, Texas, Illinois, Michigan, and Western Florida. This species is common in rice fields (Service 1986). A potentially serious epidemic of WEE was prevented in Minnesota by an extensive mosquito control effort directed at this species (Gordon 1983). *Culiseta melanura*, mainly a bird feeder, is the primary vector for spreading WEE among birds in the eastern United States (Hayes and Wallis 1977). Other species of mosquitoes implicated in WEE include *Culisetu inornata* (McLean 1975), *Aedes dorsalis* (Weber 1979), and others (Ferguson 1954).

Pigeons (Weber 1979) and house sparrows (Holden et al. 1973, Weber 1979) are implicated as important carriers of WEE. Viremia in house sparrows closely paralleled infection rates of *Culex tarsalis* with WEE virus (Hess and Hayes 1967). WEE has been isolated from brown-headed cowbirds and house sparrows in New Jersey (Scherer 1963, Karstad 1971). Other species of birds implicated in WEE include: sparrows, blackbirds, migratory waterfowl, pheasants, prairie chickens, black-crowned night herons (Horsfall 1962), shrikes, catbirds, chickadees, cardinals, bluejays, and hermit thrushes (Kissling et al. 1955). Karstad (1971) believes that birds do not carry virulent forms of WEE over long periods because of their strong and persistent antibody response. Reptiles and amphibians are suspected of being reservoir hosts for WEE (Spalatin et al. 1964), and research efforts have been directed to garter snakes (Thomas et al. 1959, Thomas and Eklund 1960, 1962).

SLE is a Type B arbovirus and clinically the most prevalent in he United States (Weber 1979, Kettle 1984). It was first isolated in St. Louis in 1933 where there were 1100 cases and 200 deaths in the city. This arbovirus is most common in the central and western United States, although cases have been recorded from all over the country. Mortality rates are highly variable, usually 10 to 30 percent east of the Rocky Mountains, but a much lower mortality west of the Rockies (Herms and James 1961). The eastern infections are predominantly urban epidemics with peak occurance and mortality in the 40 to 70 age group, especially those over 60. The western epidemics are rural and concentrated in the under 10 age group. This geographical difference is attributed to regional differences in species of vector mosquitos. The predominant vectors are: *Culex tarsalis* in the West, the *Culex pipiens* complex in the East, and *Culex nigripalpus* in Florida and Jamaica (Herms and James 1961, Parkin 1975). *C. p. pipiens* represents the *pipiens* complex in the northern part of its range, while *C. p. quinquefasciatus* is the southern subspecies. *Culex tarsalis* is more readily infected with the arbovirus at lower

viremias than the *Culex pipiens* complex. Subsequently, *Culex tarsalis* infected hosts possess milder symptoms (Reeves 1982). Similarly WEE is the mildest strain of arbovirus since *Culex tarsalis* is the primary vector. Although horses are generally considered resistant to SLE, this strain was shown to be fatal in controlled experiments (Herms and James 1961). The largest epidemic of this strain occurred in 1975, which resulted in 1815 cases nationwide, including 416 (29 fatal) from the northcentral states (Gordon 1983).

Important reservoirs for SLE are house sparrows, pigeons, house finches (Weber 1979), blackbirds (Horsfall 1962), chickens, domestic geese, doves, and herons (Parkin 1975). House sparrows are considered a major host species in some parts of the United States (Holden et al. 1973, Lord et al. 1973, 1974, McLean and Bowen 1980, McLean et al. 1983).

Histoplasmosis

Histoplasmosis is a relatively common lung disease caused by airborne spores (actually microconidia) of the fungus *Histoplasma capsulatum*. The mycelial phase of the fungus grows in some soils enriched with bird or bat droppings and releases the spores. The development of the yeast phase produces the clinical symptoms in mammals 11 to 14 days after being exposed (Weber 1979). Until the late 1960's and early 1970's, it was commonly misdiagnosed as tuberculosis (Stickley and Weeks 1985). Clinical cases fall into three major categories, acute pulmonary, chronic pulmonary, and disseminated, reflecting the relative severity of the infection (Weeks and Stickley 1984, Stickley and Weeks 1985). Acute pulmonary histoplasmosis is the most common form and is usually mild, requiring no treatment. Cold or allergy symptoms are typical. Pulmonary lesions are detectable by chest x-ray. Chills, fever, muscle or chest pains, and a cough accompany the disease. Chronic pulmonary histoplasmosis results in cavitation in the upper parts of the lungs and is characterized by a cough, sputum containing pus, anorexia, weakness, and fatigue. It may continue for months or years, and it can be fatal if untreated, usually from associated complications. Disseminated histoplasmosis results from the spread of the fungus throughout the body by the bloodstream, and is usually found only in the very young or very old. This form of the disease is characterized by an enlarged liver and spleen, paucity of leukocytes in the blood, anemia, high fever, and ulcerated lesions in the mouth. This form is usually fatal if untreated. Recovery in treated patients is about 80 percent. Serious cases of histoplasmosis can result in pneumonia, hepatitis, adrenal gland problems, skin lesions, chronic meningitis, and chronic retinachoriditis (ocular histoplasmosis--an inflammation of the choroid in the macular lutea area of the retina) (Weber 1979, Weeks and Stickley 1984).

Histoplasmosis is considered a relatively benign disease, accounting for only about 50 human fatalities a year (Weeks and Stickley 1984). An Army report (U.S. Army 1985) estimates that annually there are 500,000 infections, 5,000 individuals hospitalized, and 800 deaths in the United States due to histoplasmosis. About 90 percent of the people infected with the spores (register positive antigen serological tests) show no discernible symptoms. The severity of the infection appears to be proportional to the amount of spores inhaled (Tosh et al. 1966a, Powell et al. 1973). More than 30 million Americans and 95 percent of the population of central Kentucky are estimated to test histo-positive (Monroe and Cronholm 1976).

The most serious threat of airborne infections by *H. capsulatum* spores occur when contaminated dry soil is disturbed, producing dusty conditions. Histoplasmosis can also result from contact with items exposed to the spores. Infections have occurred among family members of roost workers whose field clothes were contaminated or laboratory

technicians processing infected soil samples (Stickley and Weeks 1985), but cases of this nature are unusual.

H. capsulatum is a widespread soil organism which has been postulated to thrive in all the world's river valleys in temperate and tropical regions, generally between 45° north and 45° south latitude (Furcolow 1960). However, it is rare or absent in arid regions like the Middle East (Selby 1975a). The greatest infections in the United States have been reported for rural central states, especially the Ohio-Mississippi Valley regions (Ajello 1967, Weeks and Stickley 1984). A good review of the historical aspects of histoplasmosis can be found in Rogers (1966). An in-depth authoritative review is provided by Weeks and Stickley (1984) or Stickley and Weeks (1985), and a brief introduction suitable for the public is Weeks' (1984b) publication. A survey of histoplasmosis epidemics between 1948 and 1970 was summarized by Monroe and Cronholm (1976). Also see Wilcox et al. 1958, Furcolow et al. 1961, d' Alessio et al. 1965, Tosh et al. 1966a, Fass and Saslaw 1971, and Powell et al. 1973 for original references.

Histoplasmosis is usually implicated with roosting birds, predominantly blackbird-starling winter roosts (Wilcox et al. 1958, Furcolow et al. 1961, Ajello 1964, d'Alessio et al. 1965, Dodge et al. 1965, Tosh et al. 1970, Weber 1979, Mott 1984). An outbreak of histoplasmosis occurred in a prison in Auburn, New York after a cleanup of bird droppings from a blackbird roosting area at the prison (Morse et al. 1985). *Histoplasma* spores can enter air conditioning or air-ventilation systems. Forty percent of the students and faculty (384) become clinically ill after inhaling spores circulated through a forced air ventilating system at a Delaware, Ohio school (Weber 1979). The source of the spores came from a cleanup of the schoolyard where pigeons and blackbirds had roosted. Histoplasmosis infections have also been associated with chicken feathers, sawdust, decaying wood, and coal dust (summary in Selby 1975a) and soils enriched with droppings from chickens (Furcolow 1965, Stickley and Weeks 1985), pigeons (Grayston and Furcolow 1953, Weber 1979), ring-billed gulls (Waldman et al. 1983), and oilbirds (Ajello et al. 1962). Cave explorers have contracted the disease from bat guano deposits (Furcolow 1965, Hasenclever et al. 1967, Lottenberg et al. 1979, Sorley et al. 1979). Since bat guano deposits may be extensive and deep, spore production may be very high, leading to severe infections.

The soil at bird roosts is often infected with histoplasmosis (Furcolow et al. 1961, Powell et al. 1973, Latham et al. 1980). A third of the 70 roost sites examined by Chick et al. (1981) in Kentucky harbored *H. capsulatum*, and human populations living near these positive sites had a significantly higher positive histo-reaction than those living near negative sites. Other studies have shown strong positive correlations between incidences of human histoplasmosis and distance from *H. capsulatum* infected sites (Furcolow 1961, Tosh et al. 1966b, Chin et al. 1970). However, living near a positive site does not necessarily mean that infections will be acquired (Menges et al. 1967b). Mott (1984) discusses some unpublished reports on the ecology of *H. capsulatum* and concludes that temperature, humidity, and pH regulate the geographical distribution and growth of the fungus. Spore formation is inhibited at temperatures above 40 °C or below 15 °C, pH < 6.6, and low relative humidity. Howell (1941) also reported that *H. capsulatum* grows poorly under acidic conditions. However, the spores can tolerate temperatures below 0 °C and above 40 °C for extended periods (Goodman and Larsh 1967) and survive within a pH range of 5 to 10 (Stickley and Weeks 1985). Histoplasmosis is detectable in soil around roosts generally after they have been in use at least 3 years (Ajello 1964, Dodge et al. 1965, Chin et al. 1970, Tosh et al. 1970, Monroe and Cronholm 1976). The high levels of nitrogen, phosphorus, and organic matter associated with older roosts apparently promote rapid growth of the fungus, and it takes this length of time and

nutrient levels for *H. capsulatum* to compete successfully with other soil organisms (McDonough 1963). However, once established in the soil, it becomes very persistent (Smith et al. 1964, Brandsburg et al. 1969). The fungus generally grows in the upper 2 to 12 cm of soil, but has been found as deep as 37 cm (Smith et al. 1966). Although *H. capsulatum* needs moisture for growth, the spores can survive many years in dry soil (Goodman and Larsh 1967).

Histoplasmosis has frequently been reported in dogs, cats, and wildlife (Rowley et al. 1954, Emmons et al. 1955, Menges et al. 1963, 1967a), but it is not a contagious disease and animals (especially birds) are neither carriers of the fungi nor help disseminate it but are infected, like man, from a source of fungal spores (Selby 1975a, Stickley and Weeks 1985). However, there is some evidence that bats may aid in spore dissemination (Zamora 1977). Birds appear to be immune to histoplasmosis, because their high body temperature (around 42 °C for typical songbirds) prevents fungal development (Menges and Habermann 1955).

Cryptococcosis

Cryptococcosis is caused by the yeast *Cryptococcus neoformans* and is distributed worldwide. Domestic mammals are frequent hosts for the fungal disease (Barron 1955), but infections in birds are rare (Keymer 1982). Early clinical symptoms in humans are not characteristic and difficult to diagnose. There are no visible early symptoms in about a third of the cases (Weber 1979). The disease usually begins in the lungs and may resemble a cold, flu, or allergies. Advanced stages of the disease commonly affect the central nervous system, mucous membranes, bones, joints, and skin, but any organ or tissue can become infected (Anderson 1975). The most serious infections may lead to cryptococcal meningitis, and inflammation of the brain and spinal cord membranes, which is difficult to diagnose and fatal without therapy. Although, cryptoccal infections are most serious in people already suffering from other afflictions, a serious infection appeared in a healthy 42-year-old Australian male who died from severe meningitis and neurological complications (aphasia and hydrocephalus) (Glasziou and McAeen 1984). The patient apparently inhaled spores from the dust and debris of a swallow nest (*Hirundo neoxena*) when he was holding a ladder for a neighbor who was dismantling the nest above him.

Pigeon droppings are considered the most notable source of *C. neoformans* (Walter and Coffee 1968a, Weber 1979, U.S. Army 1985). This yeast is carried in their intestinal tracts and develops on the nitrogen substrate creatine in pigeon manure (Kreger-Van Rij and Staib 1963). Occasionally it may be found in the tissues of diseased pigeons. The fungus has been found in 68 percent of the pigeon coops surveyed in Pittsburgh, Pennsylvania (Walter and Atchison 1966); 93 percent of those in Kansas City, Missouri (Weber 1979); and 84 percent of samples taken from old pigeon roosting areas (U.S. Army 1985). When pigeon droppings were samples, 45 percent in Morgantown, West Virginia and 36 percent in New York City were contaminated (Weber 1979). *A. neoformans* has occasionally been associated with other birds such as chickens, pheasants, parrots, parakeets, canaries, starlings, and doves. Nonavian sources of the fungus include domestic mammal pens and debris from demolished houses (Walter and Coffee 1968a, Keymer 1982).

The infection is most commonly acquired by inhaling airborne cells of the yeast under dry, dusty conditions, similar to histoplasmosis. A potential source of infection is from dried pigeon droppings on building ledges near air-conditioning systems.

Cryptococcus neoformans is sensitive to alkaline conditions. Therefore, areas of suspected contamination can effectively be treated with an alkaline wash. One half

kilogram of hydrated lime and 18 grams of sodium hydroxide should be dissolved in 12 liters of water (Walter and Coffee 1968b).

Minor Health Problems Associated With Birds

Viral

Newcastle Disease is caused by a virus and primarily affects chickens, sometimes with mortality rates of 90 percent. Turkeys, pigeons, waterfowl, and especially pheasants are susceptible. Human infections consist of the irritation and inflammation of the eyes and surrounding tissues. The conjunctivitis usually lasts for only 3 or 4 days, but courses of 7 to 8 days and up to 21 days have been reported (Hanson 1975). Recovery is almost always complete, but visual impairment has been reported. Most human cases come from diseased poultry, their products, or laboratory cultures of the virus.

Bacterial

Avian Tuberculosis. Tuberculosis is a bacterial infection that can affect any part of the body, usually the lungs, and in humans is caused by *Mycobacterium tuberculosis*. Avian tuberculosis is caused by *M. avium* and also commonly affects swine. The incidence of *M. avium* in wild bird populations is well below 1 percent for most species, but the infection rate rises sharply in captive birds with poor nutrition or living in crowded, cool, damp, poorly ventilated aviaries (Arnall and Petrak 1982). This disease is usually associated with poultry flocks, where it is highly contagious and mortality rates are high. In wild birds, avian tuberculosis is more prevalent among species that live in close association with domestic birds or stock (e.g., house sparrows and starlings) and scavengers (e.g., gulls) (Roffe 1987). *M. avium* is worldwide in occurrence, but is most common in the northern hemisphere.

Avian tuberculosis rarely affects mammals, but it has been documented in a variety of species, mainly domestic or zoo animals (Kleeburg 1975). The infection in cattle is harmless. Up until the mid-1970's, less than 100 humans had contracted the disease, generally with mild symptoms (Kleeburg 1975).

Erysipeloid. Erysipeloid is caused by the bacteria *Erysipelothrix rhusiopathiae*, also called *E. insidiosa*. This organism is common and widespread among domestic and wild animals, including fish and shellfish. Serious infections occur in swine and poultry, but humans are relatively resistant. Erysipeloid can be considered an occupational hazard, since the majority of reported cases are associated with workers dealing with animals or their products: meat, poultry, or fish processors, veterinarians, fish and game personnel, leather or soap manufacturers, etc.

Erysipelothrix infections are usually introduced through minor skin wounds (Wood 1975). In humans it appears as a swollen red to black discolored skin lesion, accompanied with a burning or throbbing pain and intense itching. Headache, fever, chills, nausea, and joint pains may also occur. Fatalities have been reported, generally in young children and old invalid patients.

Listeriosis. Listeriosis is caused by the bacteria *Listeria monocytogenes*. *L. monocytogenes* is usually found in nature as a component of a highly complex microflora, and is very difficult to isolate (Killinger 1975). Symptoms of the disease in humans include: meningo-encephalitis (inflammation of neural membranes), septicemia, endocarditis (inflammation of heart membrane), conjunctivitis (inflammation of inner eye lid), pneumonia, and pregnancy complications.

endocarditis (inflammation of heart membrane), conjunctivitis (inflammation of inner eye lid), pneumonia, and pregnancy complications.

L. monocytogenes has been isolated from many species of mammals and birds (Gray 1958, 1963, Fiennes 1982). It has also been found in silage, sewage, streams, mud, crustaceans, and fish (Killinger 1975). Some people serve as asymptomatic intestinal carriers. Common sources for human infections have been cattle, sheep, and poultry. Mortality is high in many species of birds (Fiennes 1982). Epidemiology and the role of vector species in this disease are not understood.

Lyme Disease. Lyme disease was officially recognized as a new form of inflammatory arthritis, after a 1975 human episodic outbreak in Old Lyme, Connecticut (Steere et al. 1977b). An important diagnostic marker of Lyme disease is the presence of an expanding red circular skin lesion or rash, known as erythema chronicum migrans (ECM) (Steere et al. 1977a). The first description of ECM came from Sweden in 1910 (Afzelius 1910, 1921), and the first reported case of ECM in North America occurred in Wisconsin in 1969 (Scrimenti 1970). See Dammin (1989) for a recent review of Lyme disease. Lyme arthritis has been occurring in southeastern Connecticut since at least 1972 (Steere et al. 1977b), primarily in three contiguous communities, Old Lyme, Lyme, and East Haddam (Steere et al. 1977a). Since 1982 the disease has been increasing in frequency in three main areas: the Atlantic Coast from Massachusetts to Maryland, the Midwest (Wisconsin and Minnesota), and the West (California, Oregon, Nevada, and Utah) (Ryan 1987, Wisconsin 1987). Cases have also been reported in Arkansas, Georgia, and Texas (Spielman et al. 1985). During the early 1980's, the Center for Disease Control reported over 500 cases annually, and in 1984 Lyme disease was reported from 24 states (Ryan 1987). ECM and Lyme disease have been reported from Sweden, Switzerland, Germany, France, Russia (Steere et al. 1977a, 1983a, Burgdorfer et al. 1985, Ryan 1987), and Australia (Stewart et al. 1982).

The spirochete bacteria responsible for the disease was first detected and isolated in 1982 from a tick (*Ixodes dammini*) (Burgdorfer et al. 1982), and later from patients (Steere et al. 1983b, Benach et al. 1983). The Lyme microbe has been classified as *Borrelia burgdorferi* (Johnson et al. 1984). The bacteria are transmitted by blood-feeding ticks, but other arthropods may be involved.

Lyme disease is a complex, multisymptom disorder (Steere et al. 1977a, 1983a, Ryan 1987, Wisconsin 1987). Because of the variety of symptoms and the similarities to other diseases, including an arthritis resembling rheumatoid arthritis, Lyme disease has been difficult to diagnose and many cases undoubtedly have been unreported. Lyme disease typically progresses in three stages. The disease usually begins with the characteristic expanding circular skin lesion (ECM) at the site of the bite usually 1 to 2 weeks (range of 3 to 32 days) after the patient is bitten by an infected tick. ECM usually lasts for about 3 weeks. However, about 30 percent of those infected with Lyme disease do not develop the rash. Of the 314 patients diagnosed with ECM, 48 percent developed additional multiple annular lesions, 80 percent experienced fatigue and lethargy, 64 percent had headaches, and 59 percent reported fever and chills (Steere et al. 1983a). If Lyme disease is diagnosed at its first stage, it can be treated effectively with antibiotics (e.g., tetracycline, penicillin, and erythromycin). Weeks to months after the initial ECM stage, some patients may develop neurological or cardiac abnormalities (e.g., meningitis, encephalitis, facial paralysis, inflammations of peripheral nerves, fluctuating degrees of atrioventricular blockage). Painful joints, tendons, or muscles may also occur at this stage. Patients generally recover from this second stage of the disease. The arthritic stage, if it occurs at all, manifests itself 4 days to years after initial symptoms are recognized. Steere et al. (1977a) studied 32 patients with ECM, and 19 of them

developed arthritis 4 days to 22 weeks (median = 4 weeks) after the onset of ECM. Eight more patients, who never had skin lesions, developed arthritis. Seven of the 27 arthritic patients experienced migratory joint pains, often in the knee. These attacks were generally of short duration (median = 8 days), but some persisted for months. The arthritis may become chronic with erosion of cartilage and bone.

Clinical cases of Lyme disease have been observed in dogs, cattle, and horses (Wisconsin 1987). Investigations of Lyme disease in dogs at the Lyme area in Connecticut found that 28.6 percent of the dogs (N=210) carried antibodies to *B. burgdorferi* (Magnarelli et al. 1985), and that the dogs had a history of tick exposure, joint swelling, and sudden onset of lameness (Kornblatt et al. 1985).

The following Ixodid ticks have been identified as the primary vectors of the Lyme disease bacteria: bear tick (*Ixodes dammini*) in the East and Midwest (Steere and Malawista 1979, Burgdorfer et al. 1982), western black-legged tick (*I. pacificus*) in the West (Steere and Malawista 1979, Burgdorfer et al. 1985), common black-legged tick (*I. scapularis*) in the South (Spielman et al. 1985), and *I. ricinis* in Europe (Burgdorfer et al. 1983). Other tick species suspected of transmitting Lyme disease are: the lone star tick, *Amblyomma americanum* (Schulze et al. 1984), and the wood or dog tick, *Dermacentor variabilis* (Anderson et al. 1985). These two species are also responsible for transmitting Rocky Mountain spotted fever (east of the Rockies), tularemia, and Q-fever (Center for Disease Control 1978). The lone star tick commonly feeds on ground-dwelling birds, including turkeys, quail, rails, cardinals, and chickens (Terres 1980). The common black-legged tick has also been reported to feed on birds (Center for Disease Control 1978).

The infectious bacteria of Lyme disease have also been reported in 9.5 percent of horse and deer flies (8 species, N=402), and 7.6 percent of mosquitoes (3 species, N=66) surveyed in both Lyme and non-Lyme areas of Connecticut (Magnarelli et al. 1986). Biting flies have been suspected in transmitting Lyme disease in Germany (Ryan 1987). In Sweden, an individual developed expanding skin lesions at the site of mosquito bites, and three patients in Connecticut who were bitten by deer flies developed ECM at the bite sites (Magnarelli et al. 1986). The role of arthropod vectors, other than ticks, in the transmission of Lyme disease is unclear and warrants further investigation.

Ixodes females are small ticks about 3 mm in length (males are smaller), while the larvae are about the size of a pinhead. The life cycle of *Ixodes* ticks from eggs to adults may take 2 or more years (see Steere 1989 for a recent review). Ixodid eggs are laid in the spring and hatch into larvae (August through September) which attach to rodents, birds, or other small vertebrates. At this stage, the tick may become infected with the Lyme bacteria from an infected host. Some larvae may acquire the spirochete by trans-ovarial passage (Bosler et al. 1983). The larvae molt into nymphs the following spring. Nymphs may also become infected by their hosts. Nymphs feed on a wide variety of hosts: rodents, rabbits, birds, lizards, deer, foxes, raccoons, dogs, cattle, and humans. The nymph molts into the adult in late summer, and typically feeds on large mammals, especially deer. Since the life cycle of *I. dammini* is 2 years, the nymphs feed earlier in the season than larvae (Spielman et al. 1985). Larvae feed July through September, while the nymphs feed May through July. Adult female ticks feed in the fall, winter (weather permitting), and in early spring. Immature *I. dammini* utilize an unusually large variety of hosts, at least 24 mammal and bird species, including humans (Spielman et al. 1979). However, about 90 percent of this tick's larvae and nymphs have been found to infest white-footed mice (*Peromyscus leucopus*) in the Northeast (Piesman and Spielman 1979, Spielman et al. 1985). This undoubtedly reflects the abundance of this rodent in appropriate tick microhabitats. *P. leucopus* is an abundant widespread species in forest and shrub habitats throughout virtually all of eastern and central United States. This species

is the only cricetid rodent available in these habitats at the Atlantic coastal Lyme sites. Adult *I. dammini* seek their hosts about one meter above the ground (Speilman et al. 1985). Their primary host is the white-tailed deer, but dogs and humans are also included. Deer may be an important reservoir for overwintering Lyme bacteria and adult ticks (Bosler et al. 1983). Although all three stages of *I. dammini* feed on humans, nymphs may be the most important stage for transmitting spirochetes to humans (Bosler et al. 1983). In six cases of Lyme disease where the biting tick was saved, all ticks were nymphal (Steere and Malawista 1979). The peak of Lyme disease in the Northeast occurs in the summer and early fall (Steere et al. 1977b, 1983a), suggesting that immature ticks and not adults are responsible. Contrary to *I. dammini* nymphs, *I. pacificus* nymphs rarely feed on humans, preferring rodents, rabbits, birds, and lizards (Furman and Loomis 1984, Burgdorfer et al. 1985). Adults of both species of *Ixodes* parasitize similar hosts.

Besides arthropods and humans, Lyme bacteria have been isolated from white-footed mice, eastern chipmunks (*Tamias striatus*), meadow voles (*Microtus pennsylvanicus*), woodland jumping mice (*Napeozapus insignis*), white-tailed deer, dogs, and raccoons (Anderson et al. 1985, Spielman et al. 1985). Antibodies to the bacteria, indicating exposure, have been isolated in mice, deer, raccoons, opossums, squirrels, chipmunks, horses, and dogs (Kornblatt et al. 1985, Magnarelli et al. 1985, Spielman et al. 1985).

I. dammini parasitized 44 of 62 wild songbirds comprising 18 species, in a mist-netting survey of birds in the Lyme area of Connecticut (Anderson et al. 1986). *B. burgdorferi* was isolated from a veery. This was the first time that Lyme disease bacteria was isolated from a bird. This bacteria was also isolated from seven *I. dammini* larvae which were found feeding on a common yellowthroat and a single larvae attached to a rose-breasted grosbeak. Birds may not suffer clinical symptoms from being infected by *B. burgdorferi*, but may serve as reservoirs for the bacteria, and migratory bird species may be responsible for its dispersal (Anderson et al. 1986). The role of birds and other animals, including arthropods, as reservoirs or dispersal agents of Lyme disease require further investigations. Deer and white-footed mice appear to be the primary reservoirs for Lyme bacteria. The high incidence and spread of the disease in recent times can probably be attributed to increases in deer populations.

Pasteurellosis. Pasteurellosis, also known as avian cholera, fowl cholera, or hemorrhagic septicemia, is caused by the bacterium *Pasteurella multocida*. Other species and unclassified pasteurella-like forms have also been identified in human infections (Biberstein 1975). In humans, the disease manifests itself as an inflammation of the upper or lower respiratory system, infection of internal organs (e.g., urinary bladder), or abscessed wound infections. Pasteurellosis infections are rare in humans (Harshfield 1965).

This disease is much more common and serious in birds (especially domestic and captive birds) and domestic mammals than it is in humans (Harschfield 1965, Rosen 1971, Terres 1980). In wild birds, pasteurellosis is most common in waterfowl, usually causing major annual epidemics (Rosen and Bischoff 1949, 1950, Gershman et al. 1964, Jensen and Williams 1964, Rosen 1971, Friend 1987). Explosive die-offs may involve 1,000 birds each day. This disease also occurs frequently in gulls, crows, and coots. Bird species occasionally infected include: wading and shore birds, passerines, raptors, and upland game birds (Friend 1987).

The primary sources of human infections are the bites of domestic cats and dogs or from cat scratches (Rosen 1975). Throat swabs from the tonsils of 79.5 percent of dogs examined and 90 percent of cat gum lines, yielded cultures of *P. multocida* (Rosen

1975). Although there have been large outbreaks of this disease in waterfowl, duck hunters have not contracted the disease (Rosen 1975).

Q Fever. Q fever is a bacterial disease caused by *Rickettsia burneti*. It produces pneumonia-like symptoms in human infections accompanied by severe headaches and sore eyes. The most common sources of human infections are domestic mammals or their products, usually through airborne aerosol inhalation. Ticks and other arthropods play a role in spreading the infection (Burgdorfer 1975).

Pigeons (Weber 1979) and many domestic and wild birds show natural infections and carry Q fever antibodies (Enright et al. 1971). In experimental laboratory infections of fowl, the bacteria was excreted in their feces (Fiennes 1982). Tarasevich and Kulagin (1961) believe that fowl are resistant to Q fever. Fiennes (1982) reviewed the evidence and suggests that *R. burneti* does not cause active disease in birds. The role of birds in spreading or maintaining Q fever is unknown.

Tularemia. Tularemia is a bacterial infection caused by *Francisella tularensis*. The disease ranges widely in severity and produces a wide variety of symptoms when infecting humans. It is often confused with a broad range of other diseases (Olsen 1975). Tularemia has primarily been recorded from rodents and rabbits, but many other mammal species are affected. Ticks represent vectors and reservoirs for the bacteria. The role that birds play in the maintenance or dissemination of this bacteria is not clear (Olsen 1975).

Natural infections have primarily been found in gallinaceous birds (e.g., pheasants, grouse, quail, prairie chickens), waterfowl, and predatory/scavenging species (Green 1928, Burroughs et al. 1945, Thorpe et al. 1965). Bird species vary considerably in their susceptibility to infection, and resistant species harbor the organism for extended periods in their blood and tissues, and excrete it in their feces (Lillie and Francis 1936, Cabelli et al. 1964). Infected migratory birds may have contaminated the water through their feces or carcasses and introduced tularemia to muskrats in a 1968 Vermont epidemic (Young et al. 1969).

Vibriosis. Vibriosis is a bacterial infection caused by *Vibrio fetus*. Cattle and sheep are primarily infected, causing fetal deaths and infectious abortions. Other known hosts are: poultry, swine, antelope, and primates (Bryner 1975). Up to the mid-1970's, only 92 confirmed human cases were recorded (Bryner 1975). Septicemia accompanied by severe fever is the most common clinical form of the infection in adult humans. Meningitis and encephalitis have been described in children less than 8 years of age (Bryner 1975). *V. fetus* has been isolated from house sparrow feces (Weber 1979).

Yersiniosis. Yersiniosis is a bacterial infection produced by *Yersinia pseudotuberculosis* or *Y. enterocolitica*. The former bacteria is primarily reported from Europe, rarely from the United States. The latter is also mainly found in Europe, but is also in the Americas, Congo, and South America (Mair 1975). Yersiniosis most common clinical form in humans is an inflammation of mesenteric lymph nodes, closely resembling appendicitis.

The bacteria are associated with a wide variety of mammals and birds, and have been recorded from all the usual farm, domestic, and pet species, commercially raised fur-bearers, and wild animals. Infections may be widespread in domestic and wild birds. Serious infections have been reported in: turkeys, chickens, ducks, doves, canaries, and finches (Mair 1975). The bacteria have been isolated from pigeons and house sparrows

(Weber 1979). Contact with infected animals is the apparent means for humans to contract the disease.

Plague is a bacterial infection produced by *Y. pestis*. This organism is generally spread by rodent fleas, but domestic carnivores (especially cats) may spread plague directly or through their fleas (Ryan 1987). The role of birds and their fleas in the maintenance or dissemination of *Y. pestis* is unknown. See fleas in Avian Ectoparasites (p 49).

Fungal

Aspergillosis. Aspergillosis is one of the most common bird diseases worldwide, and infections have been diagnosed in at least 19 of the 27 avian orders (Keymer 1982). *Aspergillus fumigatus* is the usual disease agent, but four other *Aspergillus* species have been reported (Keymer 1982). The fungus primarily attacks the bird's respiratory system, but necropsy has found lesions in almost any organ. It is common in free-living, captive and domestic birds, especially the young. Captive birds are apparently more susceptible than free-living individuals. Aspergillosis is a major problem in captive raptors and commonly causes mortality in captive penguins (Locke 1987b). The disease is particularly common in poultry, waterfowl, gulls, crows, and ravens. Aspergillosis is a major cause of mortality in winter blackbird roosts in Pennsylvania and Maryland (Locke 1987b).

Birds are not a source for human infection (Richard 1975, Herman 1982). Both human and birds contract the fungus by inhalation from a contaminated source (e. g., moldy food, hay, or bird droppings). Aspergillosis is considered a secondary infection in humans, since most cases are recognized only in conjunction with other lung ailments (Landau et al. 1963, Utz 1965, Heffernan and Asper 1966).

Blastomycosis. Blastomycosis is an uncommon fungal disease caused by *Blastomyces dermatitidis*. This organism is free-living in the soil (Denton et al. 1961, Denton and DeSalvo 1964). The fungus primarily affects the lungs, where it becomes established by the inhalation of spores, but may also produce lesions and ulcers on skin tissue. This disease is seen most frequently in dogs (Menges et al. 1965). Blastomycosis is not contagious and both dogs and humans must be infected from a source of spores, as in the case with histoplasmosis and aspergillosis (Selby 1975b). Apparently, *B. dermatitidis* is not associated with soils enriched with bird or bat droppings, as is the case with histoplasmosis (Denton and DeSalvo 1964). However, extracts from starling manure have been shown to stimulate growth of the fungus (Smith and Furcolow 1964). A 45-year-old horticulturist had contracted acute progressive blastomycosis 6 weeks after applying several sacks of pigeon manure as a fertilizer (Weber 1979). Subsequently, *B. dermatitidis* was isolated from the manure.

Candidiasis. Candidiasis is caused by yeasts in the genus *Candida*, usually *C. albicans*. *Candida* infections vary widely in severity from asymptomatic or mild to severe or fatal. Almost one fourth of all deaths due to fungal infections are caused by *Candida* (Anderson 1975). Approximately 25 to 30 percent of humans carry *Candida* endogenously in their mouths, intestines, or urogenital tracts (Anderson 1975). Severe infections can occur in any organ or body tissue, and are usually initiated by or follow other debilitating diseases that are unrelated to the fungus. Typical clinical cases involve skin or mucous membrane lesions, respiratory infections, septicemia, endocarditis, and meningitis.

Candidiasis is transmitted to humans by other humans, and by domestic and wild animals. Candidiasis has been reported for many avian species, especially turkeys and chickens (Sharma et al. 1970). It has been isolated from pigeons (Weber 1979).

Protozoan

American Trypanosomiasis. American trypanosomiasis is caused by the intracellular protozoan *Trypanosoma cruzi*, which may lead to the disease called Chagas' disease. The distinction between infection with *T. cruzi* and Chagas' disease is important, because the infection is far more prevalent than Chagas' disease (Neva 1975). About 5 to 10 percent of the people living in endemic areas are infected by the trypanosomes (Service 1986). Chagas' disease occurs primarily in South and Central America, but cases have been reported in the United States, mainly in the Southwest. The protozoan is transmitted by hemipterans (true bugs) in the family Reduviidae (assassin bugs) mainly *Triatoma* species (kissing bugs). The trypanosome's life cycle takes place in the kissing bug's gut, and the infectious agents are only present in the bug's feces (Kettle 1984). After a blood meal from its human host the bug defecates. The infectious stages of the parasite enter the host's skin through the bite wound, other skin abrasions, or mucous membranes. The bugs are nocturnal feeders, and humans are generally bitten in their sleep. Mammals most commonly infected and acting as reservoirs for infecting kissing bugs include rodents, opossums, guinea pigs, armadillos, dogs and cats, and other domestic animals (Neva 1975). Other hosts for kissing bugs are bats, birds, and iguanas (Service 1986). Kissing bugs are very common in South and Central American chicken coops (Service 1986). Birds are not susceptible to *T. cruzi* infections, but they may serve as sources of blood for vector bugs (Neva 1975).

Human response to *T. cruzi* infections vary widely from subclinical or asymptomatic to fatal. Symptoms also vary and may resemble other diseases. In acute infections, the trypanosomes are found in the host's bloodstream and may lead to encephalitis or inflammation of heart muscle, which can be fatal. However, most of the mortality and morbidity of Chagas' disease is due to chronic infections, which may or may not show acute symptoms in the early stages. Chronic infections are characterized by hypertrophy and degeneration of affected organs, usually the heart, but also viceral organs. Degeneration of neural and muscle tissue occurs over a period of 5 to 10 or more years (Neva 1975). A fatal heart attack is typical around 40 years of age in severe chronic infections (Service 1986).

Toxoplasmosis. Toxoplasmosis is caused by the sporozoan protozoan *Toxoplasma gondii*. This is an unusual sporozoan since it does not require an intermediate host (e. g., like *Plasmodium* that causes malaria) (Fiennes 1978). *T. gondii* is common in mammals and birds, and human infections may be as high as 50 percent of the population (Barnes 1974). Transplacental transmission (mother to fetus) can occur (Wolf et al. 1939); however, most infections are asymptomatic, even in newly born infants. When severe symptoms are present at birth, one study reported a fatality of 12 percent, while 90 percent of the survivors were mentally retarded (McCulloch and Remington 1975).

Toxoplasma is an intracellular parasite, and in response to the host's immune system forms tissue cysts, usually in the brain, but sometimes in the heart, skeletal muscle, or lungs. In severe clinical cases of the disease, the protozoan is usually associated with brain tissue causing blindness, epilepsy, cerebral calcification, mental retardation, or hydrocephalous (a large accumulation of fluid in the brain cavity). Symptoms from milder forms include headaches, fever, disorder, fatigue, encephalitis, and pneumonia. Whenever clinical symptoms of toxoplasmosis appear, congenital

infections, even if asymptomatic at birth, are usually more severe than acquired infections.

Toxoplasmosis has primarily been reported from domestic animals. Weber (1979) reports that pigeons, house sparrows, and starlings carry the disease. The main source of human *Toxoplasma* infections is from cat feces, but infections occur from undercooked lamb, pork, or poultry. The occurrence of fecal oocysts is the source of infection for all mammals and birds, including humans. These oocysts have only been reported in two genera of cats (*Felis* and *Lynx*), which includes the domestic cat. The life cycle of *T. gondii*, therefore, depends on the circulation of infection between cats and their prey (Blewett amd Watson 1983). The life cycle of Toxoplasma in cats is summarized in Fiennes (1978). With the exception of eating contaminated poultry, squab, or waterfowl, the role of avian transmission of Toxoplasma to humans is unknown.

Avian Ectoparasites

Peters (1936) found 198 species of ectoparasites on 255 species and subspecies of birds east of the Mississippi River. Boyd and Fry (1971) examined 50 belted kingfishers and found that 84 percent possessed external parasites and 98 percent possessed internal parasites.

Feather lice (Mallphaga, chewing lice) are the most abundant ectoparasites of birds (Herman 1955). Many are host specific, being restricted to a single species or genus of bird (Welty 1979, Campbell and Lack 1985). The life histories of some species of these insects are closely linked with that of their hosts (Foster 1969, Welty 1979). Several species can also be found on mammals, but apparently not man. Most species generally feed on skin or feather framents, or quill pith, but some species may supplement their diet with blood and tissue fluids. Chicken lice (*Menacanthus stramineus*) live on feathers and the blood supply of developing feathers. At least one genus feeds exclusively on fluids, and one lives in the throat pouches of pelicans and cormorants (Ash 1960). The number of lice vary greatly on individual birds; young individuals and sick birds usually possess more lice than adults or healthy birds (Terres 1980, personal observation). Feather lice are not a threat to human health.

Feather mites (Acarina: Analgoidea, Pterotichoidea, Freyanoidea), are arachnids possessing chewing mouthparts and feed on loose bird epidermis, feather lipids, oils from dermal glands, or quill substances (Dubinin 1951, Kelso and Nice 1963). These mites are generally host specific to avian families (Campbell and Lack 1985). Feather mites are presently not a pest to poultry (Matthysse 1972). However, itch or scaly-leg mites (e.g., *Knemidocoptes mutans* Sarcoptidae) cause skin scaling and crusting on the legs, feet, or beaks of wild birds and poultry (Matthysse 1972). Birds may experience difficulty in walking or perching (Carothers et al. 1974). Some itch mites are skin parasites of canines and humans. The role of birds as vectors of these mites has not been studied in any detail.

The larvae of bluebottle flies (*Protocalliphora*, Calliphoridae), the common widespread family of metallic colored flies, especially in western United States, feed on the blood and soft tissue of nestling birds, especially cavity nesters[16] or species that build

[16]Common cavity nesting birds include: woodpeckers and sapsuckers, chickadees and titmice, bluebirds, nuthatches, most wrens, some flycatchers, tree and violet-green swallows, kestrel, some owls, brown creeper, starlings, and house sparrows. See Robbins et al. (1983) for scientific names.

mud nests.[17] Mason (1944), examining 162 cavity nests, found infection rates of 94 percent for bluebirds, 82 percent for tree swallows, and 47 percent for house wrens. Fledgling deaths are often reported (Plath 1919, Mason 1944, Kenaga 1961).

The screw-worm fly (*Cochliomyia hominivorax*, Calliphoridae) lays its eggs in the wounds or nostrils of mammals, the developing maggots feed off their living host. There have been intense biological control programs for this species in southwestern and southeastern United States because of its depradation on cattle. Calliphorids and the little house fly (*Fannia canicularis*, Muscidae) have caused myiasis (fly larvae parasitism) in skin wounds, nasal cavities, intenstines, and urinary tracts of humans (Borror and Delong 1971, Weber 1979). Myiasis is rare in the United States, but more common in undeveloped countries.

Other flies whose larvae parasitize bird nestlings are *Apaulina* (Calliphoridae), *Philornis* and *Passeromyia* (Muscidae), and the European *Neottiophilum* (Neottiophilidae). Since the larvae of all of these species parasitize nestlings and the maggots are not very mobile, these flies are unlikely candidates for disease transmission in man or other birds.

Avian hosts may help to transport and disseminate nest parasites that feed on building materials, household goods, carpets, clothes, books, or food (Weber 1979, Jones 1988). Table 5 (mainly from Weber 1979) tabulates most of these pests and their association with urban bird nests.

Avian Blood-Feeding Arthropods. Blood-feeding arthropods (e.g., insects, ticks, mites) represent disease vectors that possess the potential to spread viral, bacterial, fungal, protozoan, nematode, and trematode infections among vertebrates. Wood and Herman (1943) examined 1525 western birds of 112 species and subspecies, and found that 23 percent were infected with blood parasites.

Ticks (Acarina: Metastigmata, Ixodides) are rather large, some as long as 1/2 in. after feeding, and abundant vertebrate blood-suckers. Unlike feather lice, which are usually highly host specific, ticks feed on a wide range of bird and mammal hosts. Peters (1936) reported that the rabbit tick (*Haemaphysalis leporispalustris*) was the most widespread ectoparasite of birds east of the Mississippi River, especially on ground dwelling or nesting species (Peters 1936, Ali 1963); or on raptors and scavengers that fed on rodents or rabbits. This tick lives mainly on mammals, usually rabbits, hares, dogs, cats, and horses, but rarely bites people (Hubbert et al. 1975). The lone star tick (*Amblyomma americanum*) of southcentral and southeastern United States is common on ground dwelling wild birds, including turkeys and quail, and also on domestic chickens (Terres 1980). Nestling are also infected by ticks, sometimes causing death. Since well fed ticks may survive 3 to 4 years on one meal (Welty 1979), nesting or roosting sites may be contaminated over a long period. Soft ticks (Argasidae) like *Argas*, are primarily associated with birds, domestic as well as wild, but some species of *Ornithodoros* use both bird and mammal hosts (Campbell and Lack 1985). Argasid ticks (both the multiple nymph stages and adults) generally feed on the host at nests or roosts, while the larval stage is attached to the host (Krantz 1978). A very common species is the fowl tick (*Argas persicus*) which parasitizes chickens, turkeys, ducks, geese, canaries, pigeons, and

[17] Barn and cliff swallows build mud nests. Phoebes, robins, and wood thrushes use mud, moss, grass and vegetation for nesting material. Kingfishers, bank swallows, and rough-winged swallows tunnel into earthen banks or cuts to construct their nests.

Table 5

Destructive Household Insects Associated With Urban Bird Nests

Common Name	Scientific Name	Damages	Occurrence in Nests: Pigeons	Starlings	House Sparrows
Beetles					
Furniture beetle	*Anobium punctatum*	furniture, floors, rafters, woodwork	X		
Carpet beetle	*Anthrenus pimpinellae scrophulariae*	carpets, woolens, furs, silks	X	X	X
Black carpet beetle	*Attagenus megatoma piceus*	fabrics, furniture, carpets, woolens, furs, silks, leather, feathers, powdered milk	X	X	X
Carpet beetle	*Attagenus pellio*	carpets, woolens, furs, silk	X	X	X
Lathridid beetle	*Cartodere filiformis*	cheese, jam, carpets, fibers	X		
Larder beetle	*Dermestes* lardarius	animal products, prepared or cured meats, dehydrated eggs, dried fruit, cheese, fur, feathers, animal horns, beeswax, dry food, museum specimens, rafters, structural timber	X		
Dermestid beetle	*Dermestes murinus*	skins, furs, woolens museum specimens, grains and other food stuff	X		
Hister beetle	*Gnathoncus punctulatus*	scavengers	X		
Hister beetle	*Hister carbonarius*	scavengers	X		
Hister beetle	*Hister corvinus*	scavengers	X		
Spider beetle	*Ptinus bicintus*	grain and grain products, wool, furs, textiles, old wood	X		

Table 5 (Cont'd)

Common Name	Scientific Name	Damages	Occurrence in Nests: Pigeons	Starlings	House Sparrows
Rove beetles	Staphylinidae (20 species)	scavengers	X		
Drug store beetle	*Stegobium* paniceum*	flour, grain and grain products, coffee, spices, dried hot chili peppers, animal and vegetable products,books; has even infected toxins derived from plants--strychnine and belladonna	X		
Yellow mealworm	*Tenebrio molitor*	grain and grain products, breakfast foods; can parasitise human intestines and urinary bladder	X		
Cadelle beetle	*Tenebroides mauritanicus*	grain and grain products, breakfast foods, dried and fresh fruit, nuts spices, timber	X		
Moths					
Clothes moth	*Tinea fuscipunctella*	animal products	X		
Webbing clothes moth	*Tineola bisselliella*	furniture, clothes, woolens, carpets, furs, feathers, fish meal, milk products; most destructive furniture and clothes pest in the U.S.	X	X	X
Casemaking clothes moth	*Tinea pellionella*	upholstery, leather, wool, fur, feathers; second most destructive clothes pest in the U.S.	X	X	X
Earwigs					
European earwig	*Forficula auricularia*	vegetables, fruit, flowers, garbage	X		

*This species has bored through tin cans and sheet lead.

house sparrows, but rarely feeds off mammals, including humans (Weber 1979). The pigeon tick (*Argas reflexus*) attacks pigeons and poultry, and occasionally humans, but is not known to transmit any diseases (Weber 1979). Hard ticks (Ixodidae) are also associated with a wide variety of avian species. *Ixodes brunneus* has been found on at least 64 species of birds (Boyd 1951). Blake (1964), after many years of bird-banding in North Carolina, reported that this species was the most common tick observed. Each life cycle stage (larvae, single nymph, adult) of ixodids may take place on a different host (Krantz 1978). See Lyme Disease (p 43) for the role the ticks play in the dissemination of the infective bacteria.

Red mites (Acarina, Dermanyssidae) are the best know family of avian mite parasites and are also blood-suckers (Rothschild and Clay 1957, Matthysse 1972). Three widespread species-the chicken mite (*Dermanyssus gallinae*) European fowl mite (*Ornithonyssus sylviarum*), and tropical fowl mite (*O. bursa*)-are common on both wild birds. and poultry (Peters 1936). These species have been implicated in the spread of fowl cholera and fowl spirochete, and as reservoirs for equine encephalitis (Matthysse 1972).

Larvae of the mite *Trombicula* parasitize almost all groups of terrestrial vertebrates, (the nymphs and adults are free-living, largely feeding on insect eggs). The minute larvae (chiggers) secrete powerful proteolytic enzymes which break down dermal tissue for their consumption. This action causes severe local irritation and itching in man. Chigger bites may cause extensive dermatitis on the human body, since the victim may encounter a large mass of newly hatched eggs. The inevitable scratching kills the immature mite, but the irritation lasts for several days to a week. Vertebrate hosts other than man probably exhibit a much milder reaction, since the larvae must remain attached to the host for at least 10 days or more, and severe irritation would elicit scratching or preening behavior by the host. Since chiggers attack their hosts immediately after hatching, there is no danger that they are vectors of disease transmission.

Cimicidae are a small but widely distributed family of true bugs (Hemiptera), whose members include bedbugs. About a third of the 80 species are blood-suckers on birds, mainly swallows and swifts, but also on domestic pigeons (Usinger 1966). *Haematosiphon inodorus* is common in poultry houses and bird nests in southwestern United States (Lee 1955a, 1955b, 1959). Cimicids have been found in the nests of California condors and great-horned owls (Usinger 1947), barn owls (Lee 1959), prairie falcons (Platt 1975), and wild turkeys (Lee 1955b). Cimicids feeding on birds are generally restricted to the host's nests. They are not reported to travel on birds, and therefore are not easily dispersed (Usinger 1966, Campbell and Lack 1985). Most cimicid species feed on bats (Usinger 1966). Borror and DeLong (1971) report that cimicids are unimportant as disease vectors for man.

Fleas (Siphonaptera) are mainly mammal parasites, but about 125 species (approximately 5 percent of described species) have been found on birds (Turner 1971). Although fleas are uncommon on birds, they may occasionally be very abundant in bird nests, causing problems to nestlings. Some species of fleas are restricted to the nest (Campbell and Lack 1985). All adults are blood-feeders, while the larval stages feed on nest detritus. Birds nesting in the subterranean burrows of mammals have higher flea infestations than other birds (Welty 1979). Zagniborodova and Balskaya (1965) obtained mammalian fleas from burrow nesting birds. The fleas were known transmitters of plague.

Louse flies (Hippoboscidae) are the most specialized true flies (Diptera) that feed on birds (Rothschild and Clay 1957). Some species are flightless, all possess highly specialized mouth parts. The larvae fully develop one at a time in the female's abdomen, pupating immediately after birth. Since hippoboscids are blood-suckers on birds and mammals, they possess the potential for vectors of endoparasites (e.g., protozoans, arboviruses) from birds to man. However, since separate species feed on mammal and bird blood (Bequaert 1953a, 1953b, 1954, 1955, 1957, Maa 1969, Terres 1980), birds would not be carriers for disease transmission to humans through hippoboscid flies. A malaria-like blood protozoan (*Haemoproteus*) has been transmitted into domestic pigeons and California quail (Herman 1955). Of the approximately 200 species of hippoboscids, 150 are recorded from 24 orders of birds (Maa 1969). Interestingly, some hippoboscids are widespread with broad host preferences, while others are restricted to specific habitats or stenophagy (narrow food preferences, thus high host specificity) (Bequaert 1953a, 1953b, 1954, 1955, 1957, Maa 1969). These flies generally occur at breeding sites and are not readily dispersed during migrations (Campbell and Lack 1985). However, louse flies aid in the dispersion of feather lice and some species of mites among birds (Terres 1980, Campbell and Lack 1985).

Malaria. Mosquitoes (Culicidae), blackflies (Simulidae), and biting midges or no-see-ums (Ceratopogonidae) are highly mobile blood-sucking dipterans that feed on probably all species of terrestrial vertebrates, and therefore represent vectors of disease organisms transmitted through the blood. The most important of these diseases is malaria.

Malaria has caused more deaths worldwide than any other disease. A large percentage of the population in undeveloped tropical and subtropical countries is nonfatally afflicted in various degrees, but malarial malignancies often contribute to fatalities by parasitic infections or other diseases. Before strong control efforts, malaria was common in the lower Mississippi Valley and southwestern Georgia in the early 1900's (Matheson 1944, his Figure 28). The infection is caused by a minute parasitic sporozoan[18] (Protozoa) that invades and eventually destroys red blood cells. The genus *Plasmodium* contains about 125 described species (Noble and Noble 1982) and is responsible for malaria. *Plasmodium* needs two hosts to complete its life cycles, an intermediate host (mammals, birds and reptiles) for asexual multiplication and gamete (egg) production, and a final host (mosquito) where sexual reproduction takes place. Both hosts are necessary for the life cycle, as well as the dispersal of *Plasmodium*. Most species of *Plasmodium* have birds as their intermediate hosts (Barnes 1974). About half of all described *Plasmodium* species were found to be common in New World, African, Australian, East Indies and Pacific island lizards, and occasionally snakes (Ayala 1977, 1978).

Only four species of *Plasmodium* are known to infect man, each representing a different form of infection. Three species are worldwide in distribution and account for almost all malaria cases. *P. falciparum* accounts for about half the malaria cases, and produces the most severe symptoms, often being fatal. The only other known intermediate hosts for "human" *Plasmodium* are primates possessing hemoglobin A_2 - chimpanzee, gorilla, gibbon, and New World monkeys (Geiman et al. 1969). Other mammals have not been implicated as vectors. However, experimental as well as natural infections of at least nine species of *Plasmodium* from apes (gorilla, chimpanzee) and monkeys have been reported for humans (Chin et al. 1965, Garnham 1973, Collins 1974, Collins and Aikawa 1977).

[18]Subphylum Sporozoa, Class Telosporea, Subclass Coccidia (Barnes 1974).

Many species of mosquitoes are capable hosts for *Plasmodium* affecting man (e.g., *Anopheles*, *Aedes*, and *Culex* are not only abundant and widespread genera, but commonly implicated as vectors). All species of *Plasmodium* found in birds or reptiles (some found in mammals) possess a much different cellular morphology than typical mammalian forms, since they possess a nucleolus and typical mitochondria (prominent cristae) (Aikawa 1966). Since mitochondrial cristae are necessary for the Krebs citric acid cycle in aerobic respiration (Sterling et al. 1972, Sinden 1978), other pathways must be employed by most mammal *Plasmodium*. Therefore, there are major physiological and biochemical differences between avian and most mammalian (including man) *Plasmodium*, preventing reciprocal host exchange between birds and humans (Garnham 1966). Nevertheless, similar or even identical species of mosquitoes may be hosts for both human and avian *Plasmodium* (e.g., *Aedes aegypti* is a very common example, but there are many more)

Avian malaria is geographically widespread because of the dispersal and migratory habits of birds. Species of *Aedes* and *Culex* mosquitoes are frequently implicated. Avian *Plasmodium* is not host specific and most species of the protozoan are capable of infecting a wide variety of avian taxa. About 5 percent of all birds are infected (Hewitt 1940). Songbirds (Passeriformes) are probably the most infected (Coatney and Roudabush 1949, Lund and Farr 1965), but avian malaria has been common in poultry and other domestic birds, upland game birds and waterfowl (Hewitt 1940, Lund and Farr 1965, Seed and Manwell 1977). Herman (1938) found that 60 percent of the red-winged blackbird population on Cape Cod was infected with avian malaria. Avian malaria rates of 97 percent have been reported in California quail (Welty 1979). Infestations may be very local. Fallis and Trainer (1964) reported that mallards were 100 percent infected in one area, but only 10 percent of the mallards 80 km away carried the disease.

Two additional genera of blood protozoans are implicated in avian malaria: *Haemoproteus* and *Leucocytozoon*. The latter is the most important blood parasite of waterfowl, and is generally transmitted by black flies (Welty 1979). Other haemosphoria in birds are spread by louse flies, blackflies, or midges (*Culicoides*), see Fallis et al. (1974) and Noble and Noble (1982).

5 BIRD MANAGEMENT STRATEGIES

Introduction

This section summarizes the wide variety of approaches that have been used to control bird pests. Specific references should be consulted if more details are required. Lucid and Slack (1980), Lefebvre and Mott (1983), Timm (1983a), and Besser (1985) are particularly excellent references and they also contain a rich bibliography. Another good source of references is U.S. Fish and Wildlife Service (1984). Conference proceedings dealing with wildlife damage control are also a good source of information and references: Bird Control Seminars, Bowling Green State University, Bowling Green, OH; Vertebrate Pest Conferences; Great Plains Wildlife Damage Control Workshops; Eastern Wildlife Damage Control Conferences.

This section should be used in conjunction with Chapter 6, **Specific Problem Management**. Although small or local problems may be resolved using some of the methods discussed here (e.g., exclusion, porcupine wire, sticky repellents), large or persistent problems and especially the use of toxins should be handled by experienced animal damage control professionals. The initial contact should be with the state agency involved with wildlife or animal damage. The Departments of Conservation, Natural Resources, or Fish and Game in your state will know whom to contact. The Federal Animal Damage Control Program has research stations throughout the country administered by the Denver Wildlife Research Center, Building 16, Denver Federal Center, Denver, CO, 80225-0266. The Animal and Plant Health Inspection Services (APHIS) of the U.S. Department of Agriculture has established state offices for providing assistance in wildlife and bird damage control. Appendix C contains the addresses and telephone numbers for current state directors. Although there are many reliable private pest control firms that deal with bird problems, some may jeopardize environmental considerations and safety for assured bird kills, profit, or time/manpower savings.

Architectural/Structural Considerations

Most architectural/structural considerations for managing nuisance birds are "after the fact"; the initial design criteria are inflexible or modifications are impractical. Nevertheless, the insight of an experienced bird damage control consultant during the planning/design stages of constructing buildings, lock and dam complexes, aircraft hangars, etc. could save problems and money for the entire lifetime of the project after it is completed. All types of ledges, beams, nooks or crannies, decorative or ornamental architecture, open vents or breathers, and irregular surfaces are potential nesting or roosting sites. Building ledges and beams could be constructed on a 45° angle. Although the girder design of bridge structures cannot be compromised, some structural beams or girders could possibly be designed at a 45° angle. Pigeons prefer to perch on flat surfaces, occasionally gentle or moderate pitches. Openings and crevices could be kept to a minimum. All of these considerations are common sense approaches. Of course, aesthetics or specific contemporary designs or constraints will take precedence over potential bird problems. However, there are numerous facilities where aesthetics is secondary to serious bird management (e.g., large warehouses and aircraft hangars). It would be more economical to conceal internal beams in the design stages than to do it after the structure is completed. This is also the case with crevices, openings, or potential openings where birds can gain access into structures. Concrete surfaces should be constructed as smoothly as possible.

Habitat Modifications

Birds are well known to select specific features of the habitat for their environmental needs in providing nesting, feeding, shelter, and roosting requirements. Some species (e.g., Kirtland's warbler, golden-cheeked warbler, black-capped vireo, and ovenbird) have various restrictive habitat requirements, and therefore are very susceptible to habitat manipulations or fragmentation. Unfortunately, most pest bird species are not only generalists but respond very favorably to most of man's landscape changes. Probably the best example of habitat modification to effectively discourage bird pests is the thinning or pruning of trees and shrubs to control roosting blackbirds and starlings or birds around airports (see **Bird Roosts**, p 100).

Habitat/environmental manipulations to control bird pests requires site - as well as species-specific knowledge concerning food and water availability, nesting sites, resting places, and shelter. An experienced bird damage control expert after a period of observations can usually make recommendations for environmental manipulations. Sometimes a minimal effort is highly beneficial, such as minor landscape changes, reductions or increases in grass mowing, or improved garbage management. However, major environmental manipulations may be infeasible or uneconomical, particularly if continual maintenance is required.

Environmental considerations at airports provide the most experience for evaluating the effectiveness of controlling bird pests with habitat modifications. Since bird-aircraft strikes present potentially high human safety risks, a great deal of effort has been made to manage birds in the vicinity of airports (Seubert 1966, Canadian Wildlife Service 1971, Blokpoel 1976, Harrison 1976, Lefebvre and Mott 1983, Will 1983, Walker and Bennett 1985). Blokpoel and Lefebvre and Mott's publications are particularly informative sources for the use of habitat manipulations in bird management strategies.

Gulls are the bird species most frequently involved in bird-aircraft collisions (Blokpoel 1976). Therefore, garbage dumps should be located beyond 3,000 m of jet aircraft runways and 1,500 m for propeller powered aircraft (Federal Aviation Administration 1974). A European-Mediterranean Regional Air Navigation Meeting recommended that garbage dumps should be located beyond 8 km of airports (International Civil Aviation Organization 1978).

Land-use planning in the vicinity of airports should be a strong priority (Harrison 1976). Golf courses, grain agriculture or storage, fruit and nut orchards, lakes. ponds, and marshes are all sites that attract large bird populations.

Lakes, ponds, marshes, and temporary standing water, regardless of size, water depth, or permanence are generally eliminated, since these attract waterfowl, both shore and wading birds, in addition to large numbers and varieties of songbirds. Shallow water is much more attractive to most birds than deep water. Gulls, ducks, geese, swans, herons/egrets, cormorants/anhingas, ibises, storks, cranes/rails, kingfishers, and a variety of shorebirds (sandpipers, plovers, etc.) are mostly large birds strongly attracted to wetland sites and hazardous to aircraft (Seubert 1966, Canadian Wildlife Service 1971, Blokpoel 1976). Depressions in the vicinity of runways are leveled off since they collect runoff or rain water.

Birds can be excluded from ponds by the use of overhead stainless steel wire, nylon monofilament line, or netting (see **Exclusion**, p 58 and *Monofilament Line*, p 59.)

Another major bird control strategy at airports is the management of grass height (Lefebvre and Mott 1983). Short grass (5 to 10 cm) is favored by Canada geese, gulls, shore and wading birds, crows, pigeons, and starlings. Geese prefer to graze on short lawns, which are also ideal for starlings probing for lawn grubs. All these species require open habitats to visually monitor approaching predators.

Long grass (15 to 40 cm) attracts pheasants, some quail species, ducks, meadowlarks, bobolinks, dickcissels, and grassland sparrows. Even the presence of only a few shrubs that provide perching or nesting sites above the grass layer and/or weeds encourage a much broader diversity of song birds. Tall grass provides suitable habitat for many small mammals: deer and harvest mice, voles, cotton rats, rabbits, shrews, and moles. Short grass mainly attracts ground squirrels and sometimes moles. These small mammals attract hawks and owls, especially just after tall grass or weeds are mowed. Hawks are known to follow harvesters, combines, or mowing equipment to forage on the disturbed insects, mammals, and birds. Tall grass also harbors dense insect populations, including grasshoppers. Grasshoppers are prime prey for kestrels, gulls, herons, and egrets. Insects and earthworms are often controlled at airports by insecticides and small mammals by trapping or the use of toxins (Lefebvre and Mott 1983).

Specific recommendations for grass height vary geographically. The United Kingdom, Canada, and the Air Force have each found different heights to be optimal (Lefebvre and Mott 1983). U.S. Fish and Wildlife Service recommendations are to maintain grass at 15 to 25 cm in height where gulls and small birds are a problem and 13 cm or less where these species are not a problem (Lefebvre and Mott 1983).

Fruit bearing trees, shrubs, and vines attract a wide variety of birds, sometimes in large flocks. Common fruit-eating species include: starlings, robins, catbirds, cardinals, orioles, thrashers, mockingbirds, thrushes, finches, grackles, and waxwings.

Exclusion

Mechanical exclusion, generally by hardware cloth, poultry screening, or netting, is the most effective, permanent, and safe way to eliminate local problems with nesting, roosting, or perching bird pests. Hardware cloth is very strong and an effective means of preventing birds from nesting or entering openings and landing on ledges. However, to cut costs, at least some manufacturers have reduced the thickness of their zinc-galvanized coating. This has resulted in premature rusting and screen failure in 3 years of outdoor exposure. Aluminum screening is usually prohibitively expensive. Ultraviolet-(UV)-stabilized polypropylene netting or screening is available in a variety of mesh sizes and strand thickness from many vendors (Appendix D). Black is the usual color but other colors are available, including yellow. Plastic netting/screening is cheaper than hardware cloth and much easier to handle and apply. Plastic screening may have to be replaced more often than the better grades of hardware cloth. Although initial costs may be high for materials and labor, exclusion may represent a favorable solution in the long run, since it is so effective, and if done correctly, is a permanent solution. Care should be taken to insure that the screen openings are sufficiently small and that the screening is completely and firmly attached. Birds can fit through surprisingly small openings relative to their body size, and they can easily gain access through weak or inadequately attached screens. Plastics and fibers may possess short life-spans because of weather deterioration, especially exposure to the UV portion of sunlight. However, the new UV-stabilized polypropylene screening or netting should possess good weathering ability. Although nylon is strong, it deteriorates rapidly when exposed to sunlight. UV stabilization may not be as effective with nylon as it is with polypropylene.

A polyvinyl chloride (PVC) clad polyester yarn netting (Appendix D) has been designed primarily to protect masonry, buildings, structures, ornamental architecture, and statues from pigeons. It is available in gray, beige, and red-brown colors, possesses UV stabilizers, is very flexible, nearly invisible, and relatively inexpensive.

Small openings or vents can be permanently blocked with wood, sheet metal, or masonary to prevent bird access.

Netting has been a highly effective method for protecting some agricultural crops. Although expensive in materials and labor, it has been cost effective when protecting relatively small areas of valuable crops that are heavily depredated by birds such as blueberries, strawberries, grapes, or commercial flower and vegetable seed crops.

Monofilament Line

Exclusion through the use of an overhead canopy of 10-gauge stainless steel wire or 23 to 45 kg test nylon monofilament line has been used successfully for several species of larger birds, particularly gulls. Steel wire has proven effective in excluding gulls and other large wading and fish-eating birds from fish ponds and water supply reservoirs (McAtee and Piper 1936, Amling 1980). Ostergaard (1981) used nylon monofilament fishing line to exclude gulls from fish ponds. Blokpoel and Tessier (1984) successfully used both stainless steel and nylon monofilament line in excluding ring-billed gulls from two large public places--Toronto City Hall Square and Ontario Place. The stainless steel wire was stronger and longer lasting than the monofilament but was much more expensive and difficult to install because it tended to kink. The monofilament line was economical and easy to install, but it was broken occasionally by colliding birds. Additionally, nylon deteriorates upon exposure to sunlight's UV rays. This exclusion method works very well for gulls since these birds fly and glide in open areas and do not like to maneuver around obstacles, particularly if the obstacles are difficult to see or surprise the gull. The lines (or wire) are generally used 30 cm to 6 m above the ground or water in a parallel, zig-zag, or grid pattern (Lefebvre and Mott 1983). Spacing between the lines (or wires) is species specific: 1.2 m for gulls, 60 cm for mergansers, and 30 cm for great-blue herons and terns (Salmon and Conte 1981). Small herons (e.g., green and black-crowned night) can surprisingly negotiate closely spaced wires and therefore require netting (Salmon and Conte 1981).

Trapping

Trapping has not generally been effective for grain depredations since large numbers of birds cause damage over extensive areas, but has sometimes been successful for removing birds from orchards. Decoy traps of various designs are commonly used to capture flocking species (Weatherhead et al. 1980b, Lefebvre and Mott 1983). Small local problems are often successfully handled by live-trapping with subsequent release to another area, or unprotected species can be disposed of, usually with vehicle exhaust fumes. The principle advantages of live-trapping are minimal hazards to nontarget species and accepted public attitude. Cannon nets were originally designed to capture Canada geese and mallards (Dill and Thornsberry 1950). The original design has been modified to capture a variety of bird and mammal species (Grieb and Sheldon 1956, Turner 1956, Marquardt 1960, Lacher and Lacher 1964). Hawkins et al. (1968) replaced cannon projectiles with quick-burning, high thrust, recoilless rockets. Rocket design nets have been used to capture a variety of wildlife, including cowbirds, turkeys, Canada geese, and bald eagles (Arnold and Coon 1972, Grubb 1988). Grubb's publication includes complete design plans for a portable rocket-net system. Guidelines for using cannon

rockets can be found in Dill (1969) and Bloom (1987). Trapping success, strategies, and trap construction are to some extent species specific. Therefore, further details can be found in the section pertaining to species specific management strategies.

Shooting

The use of a .22 rifle (lead cartridges or dust shot) or a .410 shotgun is a very effective and simple way to eliminate small numbers of local bird pests. However, there may be problems with local ordinances, public attitude, safety hazards, or federally protected migratory species. Shooting should be used only as a last resort and would be more appropriate in rural areas.

Chemosterilants

Ornitrol® is a whole kernel corn bait treated with 0.1 percent 20,25-diazacholesterol dihydrochloride. It is only registered for use on pigeons, although it is effective on sparrows. This compound produces temporary sterility by inhibiting embryo formation in the egg. Although it is harmlesss to birds at recommended dosages, it is lethal if high concentrations are consumed. For it to be effective, female pigeons must be fed Ornitrol for 10 days, which produces sterility for about 6 months (Courtsal 1983). Therefore, the treatment must be done twice a year, initiating in February-March when reproduction is low. Prebaiting (see **Toxins**, *Introduction*, p 74) for 10 to 14 days at selected sites is recommended before using Ornitrol bait (Courtsal 1983).

Ornitrol has not been successful in controlling pigeons. Erickson (1983) reported that Ornitrol treatment for pigeons on a college campus resulted in only 15 to 30 percent infertility, and the birds laid fertile eggs in their second clutch after treatment. Therefore, it was not effective for reducing populations. There are four main problems with Ornitrol.

- o Because there is a time lag, it cannot solve immediate problems.
- o All the females in the population must consistently feed on the bait for the entire duration of the treatment.
- o There is usually a continued immigration of fertile females from surrounding areas.
- o Having a large sterile population of pigeons may not solve a persistent local problem.

Ornitrol chemosterilization has also been tried with male red-winged blackbirds. Although the results showed high annual variation, the researchers reported that Ornitrol shows promise of reducing populations (Lacombe et al. 1986). The timing of Ornitrol application was critical, since it is only effective during the testicular growth phase of the red-wing's annual cycle (Lacombe et al. 1987).

Wetting Agents

The use of wetting agents (detergents) is restricted to the Division of Animal Damage Control, U.S. Department of Agriculture. The only chemical registered at this

time for large-scale lethal control is the industrial surfactant Tergitol®* (PA-14) for use on blackbird/starling roosts (Lefebvre and Seubert 1970, U.S. Army 1975). Tergitol has also been used to control house sparrows (Fitzwater 1983). Applied in a weak aqueous solution, the surfactant dissolves the waterproof oil coating the birds' feathers. However, very rigid weather conditions are necessary for this treatment to be effective; at least 1.3 cm of rainfall shortly after treatment followed by temperatures of 5 °C or lower (U.S. Army 1975, Lustick 1975, 1976, Lustick and Joseph 1977, Weatherhead et al. 1980a, Mott 1984). Under these conditions, body heat loss by the birds exceeds heat produced by basal metabolism, resulting in hypothermia. As their body temperature drops, unconsciousness, damage to the central nervous system, and death follow. The dying birds do not exhibit alarm or distress behavior. At the concentrations used, the chemical is safe to plants and other animals, with the possible exception of some potential aquatic hazards.

Since stringent weather requirement place severe restrictions on the practical applicability of Tergitol, a new delivery system has been developed and is presently being evaluated (Stickley et al. 1986). The system consists of overhead sprinklers, irrigation pipe, and a proportioning valve that allows Tergitol to be metered into water pumped from a fire hydrant. After the birds are sprayed with the Tergitol solution, enough water is provided by the sprinkler system to thoroughly wet the birds.

Repellents

Wire Perching Barriers

Porcupine wire (Nixalite® and Cat Claw®) has been developed to prevent birds from landing on ledges, beams, girders, gutters, roof edges, signs, or the complex decorative architecture found on buildings. Nixalite (two models) consists of a strip approximately 10 cm wide and 9.5 cm high of sharp 1 mm wire (40 per 10 cm of length) projecting in a 180° arc from a narrow (6 mm) flexible base. Constructed of 302 stainless steel, maintenance is minimal. The bases can be attached to almost any surface with a variety of stainless steel hardware or adhesives. Nixalite provides a manual for applications and installations.

The practicality of Nixalite is limited by the size of the surface area to be protected. Porcupine wire is most practical with relatively narrow surfaces. A single strip protects a ledge 5 to 10 cm wide. A half-width 90° strip is also available for ledges less than 5 cm in width. Two strips will protect a ledge up to 22 cm in width, and five strips are necessary for a 60 cm wide ledge (Nixalite Applications Manual). Although Nixalite is expensive ($350 per 30 m), it represents a permanent and effective solution; therefore, it may be cost-effective.

A new product called "Bird Barrier" has been marketed to deter birds from roosting on ledges. It consists of 1 mm stainless steel wire displayed in a 10 cm diameter spiral, which is attached to a 2 cm wide stainless steel strap. Birds cannot perch on the spiral since it is free to pivot on the strap attachments. Its attachment is identical to that of Nixolite. This product retails for $10.66 per meter, less when larger quantities are ordered. An advantage of the product is its low visibility when in place on building ledges.

*See Appendix E for chemical nomenclature.

Bird Barrier is also available as a "flex-coil" which very closely resembles the "Slinky" children's toy. The flex-coil can be cut to desired lengths and is easier to attach where the mounting surfaces are complex, such as curves, angles, and edges, or to use as a filler for the strap product. The flex-coil comes as a single spiral coil, covers about 6 meters, and retails for about $40.00.

Bird Barrier has been reported to be effective against pigeons, starlings, and swallows at residential, industrial, and municipal localities (Esther Stevens, Bird Barrier Inc., personnel communication). Larger units are available for gulls and larger birds.

Electrical Shock

The Avi-Away® bird control system consists of a horizontally mounted cable which receives electrical pulses from a control unit, much like an electrical cattle fence. Typical installations of the cable include mounting it 4 to 6 cm above a ledge or just beneath the top of open airport hangar doors. Avi-Away cables can be mounted on or around a great variety of exterior structures or they can be used inside buildings (Avi-Away bulletin). The cable appears as a perching site, and a landing bird completes the electrical circuit between two wire conductors durably embedded in each lateral side of the cable. The bird receives a nonlethal shock and may emit an alarm or distress call when flying away. This behavior often disperses other birds in the immediate area (Avi-Away bulletin). Its manufacturers claim complete avoidance of the area after the birds have had a few experiences. Lefebvre and Mott (1983) report that electrical shock devices are generally not effective because the thick skin of the birds' feet provides excellent insulation. Furthermore, electrical devices of this nature require excessive maintenance.

Electrocution is a possible way of eliminating avian pests in small areas when there is a minimum risk to nontarget species and human safety precautions are taken (Jacob and Zajane 1965).

Sticky Contacts

Polybutenes (polybutylenes), polyisobutylenes, and polyethylenes represent a family of high molecular weight hydrocarbons that possess high viscosity. They are used as lubricants and additives (e.g., STP engine treatment) or as a wide variety of sticky compounds (e.g., Tanglefoot®, Roost No More®, and 4-The-Birds®) to keep damaging insect pests from climbing up trees, in roach motels and insect traps, in mouse traps, and in repelling perching, roosting, or nesting birds. Polybutenes, when used as sticky bird repellents, range in concentration from 2 to 97 percent. The remaining ingredients consist of one or more additives that aid in surface adhesion, control viscosity, or increase the compound's irritating properties. Frequently used additives include: mineral oil, lithium stearate soap, diphenylamine, zinc oxide, hydrogenated castor oil, petroleum naphthalenic oils, paloja, petrolatum, resins, calcium soaps, and aromatic and aliphatic petroleum solvents (Jacobs 1983). Tests by the Air Force indicated that all the products they evaluated were equally effective and similar to ordinary automotive bearing grease (Lefebvre and Mott 1983).

Roost No More is available in two products possessing different viscosities: a liquid for treating trees, shrubs, or vines and a paste for applying to ledges and other surfaces. The paste comes in a cartridge and is applied with a standard caulking gun. (Aerosol cans are available for small applications like window sills or air-conditioners.) A single cartridge will deposit a 1 cm bead 3 m long. Parallel strips 7.5 cm apart for pigeons and 5 cm apart for starlings should be applied on ledges or beams 1.25 cm from the edges

(Roost No More Applications Manual). It is imperative that sticky compounds are applied over clean, dry surfaces. When metal surfaces are to be treated and air temperatures are greater than 32 °C, 5 cm waterproof masking tape should be used to insulate the compound from the metal. Tape also protects surface discolorations and greatly facilitates removal of the compound.

Although sticky agents have been effective under ideal conditions, a common user complaint has been their short life-span and the necessity of repeated applications (Roost No More claims their products to be effective for a year). Sticky compounds quickly become ineffective in dusty, sandy, sooty, or windy conditions. They are sensitive to the weather, melting and running in hot weather and becoming brittle in the cold. Additionally, they are messy to work with, affect aesthetic appearances, may cause discoloration, and may interfere with mechanical or moving parts. These compounds are impractical to apply to large surface areas or to complex or inaccessible structures. Furthermore, all available sites must be treated or the birds will merely relocate nearby.

Mineral oil has been treated with bentonite clay (0.3 percent by weight) to produce a "non-drying film" that has been used on ledges to deter roosting birds (dialkyl ammonium bentonite and alkyl benzyl dimethyl ammonium bentonite) (Jacobs 1983).

Since sticky compounds are inexpensive and easily dispensed (assuming reasonable access), it may be worth the effort to experimentally determine if they are effective for a specific bird problem.

Chemical

Naphthalene. Naphthalene flakes or pellets (moth balls) have been used indoors or in small enclosed areas to repel nesting or roosting birds, generally pigeons, starlings, and house sparrows. This compound is registered for use against these three species in attics and wall voids (Jacobs 1983). The recommended dosage is 1 kg for 25 m^3 (Hawthorne 1980).

However, in a recent publication, Dolbeer et al. (1988) reported that there were no experimental results verifying naphthalene as a bird repellent. Their carefully executed experiment showed that starlings are not repelled by it. They concluded that birds may not be as sensitive as mammals to irritants such as naphthalene or capsaicin. Therefore, the use of naphthalene as a repellent should no longer be recommended.

Methiocarb. Methiocarb or Mesurol® (3,5-dimethyl-4-[methylthio] phenyl methylcarbamate) (Mobay Chemical Corporation), an insecticide, is a very effective avian repellent that produces a conditioned aversion in birds by reinforcing a "bad taste" to its intoxicating effects (Rogers 1974, Conover 1984a). Schafer and Brunton (1971) demonstrated that rice treated with low concentrations (< 0.16%) repelled birds, and that it was effective with a wide variety of species, including blackbirds, starlings, and sparrows. Guarino (1972) reported methiocarb to be highly effective at protecting agricultural crops. Mason and Reidinger (1982, 1983a, 1983b) reported that color, as a visual cue, may improve or reinforce the food aversion learning response in blackbirds. Similarly, house finches (Tobin 1985a) and European starlings (Tobin 1985b) used visual cues for deteeing methiocarb-treated grapes.

In a laboratory-controlled experiment, Mason (1989) demonstrated that the effectiveness of Methiocarb was improved by the addition of methyl anthranilate (avian repellent) and calcium carbonate ($CaCO_3$). Methyl anthranilate acted as a chemical cue (see p 66), and the white residue of $CaCO_3$ acted as a visual cue (Bullard et al. 1983), to

enhance methiocarb-induced food avoidance in red-winged blackbirds. Apples were used as bait. The compound has been reported to be effective with a wide variety of species, including blackbirds, starlings, sparrows, finches, pheasants, and a variety of tropical species. Apparently, the compound does not kill many birds (it mainly produces intoxicating and erratic behavior), and nontarget bird species suffer minimal damage (Holler et al. 1982).

Methiocarb has been used in two different ways for grain crops (Besser 1985). It can be applied at low concentrations (e.g., 0.1 to 0.5 percent by weight) to the seeds just before sowing, and thus offer protection to the sprouting seedlings, or it can be applied as treated bait (1.5 to 10 kg of active compound per hectare) to protect ripening crops. Seed treatments have been reported to reduce bird damage to sprouting corn (West et al. 1969, Guarino and Forbes 1970, Hermann and Kolbe 1971, Stickely and Guarino 1972, Ingram et al. 1973, Linehan et al. 1975); sprouting rice (Besser 1973, Calvi et al. 1976, Mott et al. 1976, Ruelle and Bruggers 1979, Holler et al. 1982); and sprouting sorghum and soybeans (Calvi et al. 1976). Methiocarb has also been successful at protecting ripening grain crops: rice (DeHaven et al. 1971, DeGrazio 1974, Holler et al. 1985; sorghum (Mott et al. 1974, Mott and Lewis 1975, Bruggers 1976, Calvi et al. 1976); wheat (DeGrazio 1974); and sweet corn (Stickley and Ingram 1976, Woronecki et al. 1981). The effectiveness of Methiocarb to protect crops has generally been reported as being successful, but see Mitchell et al. (1975).

Ring-necked pheasants were the only birds reported damaging sprouting corn in five states (Iowa, Idaho, Indiana, Kansas, and Maine) in a survey by Stone and Mott (1973b). West et al. (1969) demonstrated that a latex adhesive containing 0.5 percent methiocarb was effective in protecting sprouting corn from pheasants in South Dakota. Besser and Knittle (1976), at experimental plots located in Iowa and South Dakota, evaluated a graphite formulation developed by Mobay Chemical. At both sites, but especially in Iowa, significantly less damage was inflicted to sprouting corn by pheasants in treated fields compared to control fields. Two weeks after they were planted (and after 3.6 cm of rainfall) the seeds were analyzed for active residue. Although only 6 percent of the theoretical amount applied still remained, it was enough to be detected by pheasants. Holler et al. (1982) similarly reported that after three weeks, less than 6 percent of the original treatment remained (140 ppm*), but laboratory studies indicated that 50 to 100 ppm were still effective at repelling blackbirds.

Ploceid weavers (Ploceidae) are the most destructive bird family feeding on African grain crops. The red-billed quelea (*Quelea quelea*) is probably the most widespread and destructive species (Crook and Ward 1968, DeGrazio 1974, DeGrazio and Besser 1974, Bruggers et al. 1989). Fenthion is the avicide most commonly used to spray quelea, and an estimated one billion quelea are killed annually throughout Africa in hundreds of nesting colonies and roosts (Ward 1979). However, Fenthion causes secondary toxicity to predators and scavengers (See *Contact Toxins/Toxic Perches*, p 77). After Fenthion spraying operations in Kenya, dead and dying raptors have been reported (Thomsett 1987).

Methiocarb offered excellent protection to ripening sorghum from a wide variety of weaver species, starlings (*Lamprotornis chalybaeus*), and green pigeons (*Vinago waalia*) (Bruggers 1976). DeGrazio (1974) also reported a great deal of success in repelling weavers from ripening rice and wheat in Tanzania. Studies by Shumake et al. (1976) demonstrated that the red-billed quelea was six times more sensitive than red-winged

*1 ppm = 0.0001 percent.

blackbirds to the effects of methiocarb. House sparrows are about twice as sensitive as red-wings.

Luder (1985) has recently shown that the extent of red-billed quelea damage to ripening wheat in Tanzania was closely related to the association of weedy patches among the wheat. Not only are weed seeds this species' staple diet, but red-billed queleas have difficulty landing on wheat spikes in dense pure stands of wheat. The presence of weeds which were two to three times taller than the wheat, or thick bushy plants, formed stable feeding perches for the depredating birds. Therefore, in this case, producing a higher quality crop may be more effective for nuisance bird management than chemical treatments.

Methiocarb has been used successfully in Uruguay to appreciably reduce damage to sprouting soybeans, rice, and sorghum, and to ripening sorghum by doves and pigeons (*Zenaida auriculata, Columba maculosa, C. picazuro*), blackbirds (*Agelaius ruficapillus, Molothrus badius, M. bonariensis, M. rufoaxillaris*), and ducks (*Dendrocygna viduata, Anas flavirostris, Netta peposaca*) (Caivi et al. 1976).

Methiocarb has also been successfully used to reduce bird damage to fruit: sweet cherries (Guarino et al. 1973, 1974); sour cherries (Guarino et al. 1974); lowbush blueberries (Bollengier et al. 1973); highbush blueberries (Stone et al. 1974, Conover 1982); and grapes (Guarino 1972, DeHaven 1974, Crase et al. 1976, Bailey and Smith 1979, Menzies 1979, Rooke 1984); but see Dolbeer et al. (1973), Stickley and Ingram (1973), and Schemnitz et al. (1976). In a two year experimental study, Conover (1982) concluded that methiocarb was more economical and equally effective as netting in reducing bird damage to Connecticut blueberries. The chemical was effective on all bird species that preyed on blueberries: starlings, blue jays, mockingbirds, robins, northern orioles, and brown thrashers.

Rooke (1984) found that methiocarb was an effective agent for protecting Australian grapes from gray-backed white-eyes (*Zosterops lateralis* - white eyes are small common Old World passerines). As in other species that were reported and discussed above, this species used a taste cue when forming an aversion to the treated grapes.

The effectiveness of methiocarb and the degree of protection it offers depend on a variety of factors. Its use requires a trial period to adjust to site- and species-specific conditions. A common problem (e.g., Martin 1976) is poor adhesion of the compound to the surface of the grain. Although various adhesives and a latex slurry have been developed and used successfully in Germany and in experimental trials, they have not been accepted by corn growers in the United States (Besser and Knittle 1976). A hypothetical component of its success in many applications is that methiocarb significantly reduces insect populations, since it is also an insecticide. This alone may keep blackbirds and starlings out of treated fields, since these species feed very heavily on grain field insects (Woronecki et al. 1981). Most researchers do not accept the insecticide hypothesis as being important (e.g., Schafer and Brunton 1971, Rogers 1974, 1978, Rooke 1984). The relative importance of reduced insect populations has not been adequately addressed.

Methiocarb has also been effective at reducing the use of lawns and golf courses by free-ranging Canada geese (Conover 1985b). A single application of 3.0 kg/ha was used for deterrence. Similar results were obtained in controlled experiments with captive

geese. In an experimental trial, Canada geese fed significantly less on a Methiocarb treated rye crop, but a single application was not sufficient to provide winter-long protection from geese (Conover 1989).

Dimethyl Anthranilate. Mason et al. (1985) recommended dimethyl anthranilate (DMA) as a livestock feed additive to repel birds. Concentrations approaching one percent of the active ingredient are recommended for reducing starling and blackbird depredations at livestock feeding operations (Glahn et al. 1989). DMA is an inexpensive nontoxic food additive (grape flavoring) readily accepted by mammals and approved for human consumption, but apparently offensive to birds. Even in low concentrations (0.28 percent) birds find the compound unpalatable. Initial field tests indicated that DMA-treated cattle pellets and poultry crumbles significantly reduced feed consumption by birds (starlings represented 77 to 90 percent of the bird individuals). Birds in this study, as well as a previous laboratory evaluation (Mason et al. 1983), did not become accustomed to the compound.

DMA has been shown to be aversive to starlings (Mason et al. 1983, 1985, Avery et al. 1988), red-winged blackbirds, Japanese quail, pigeons, jungle fowl, herring gulls (Kare and Mason 1985), ring-necked pheasants, mallard ducks (Bean and Mason 1987), and Canada geese (Mason and Clark 1987). Other anthranilate derivatives that are as aversive as DMA, at least to starlings, are methyl, isobutyl, ethyl, and isobutyl methyl anthranilate (Mason et al. 1989). Volatility of respective anthranilate derivatives was a critical feature of their detection and avoidance.

Odor perception in birds is mediated by olfaction (smell) and nasal trigeminal chemoreception (Mason et al. 1989). Chemoreception is an animal's chemical sense, designed to protect it from exposure to irritants. Although both olfaction and chemoreception were involved with the starling's ability to detect anthranilates, experimental evidence suggested that chemoreception was more important (Mason et al. 1989).

The Bird Damage Control section of the Denver Wildlife Research Center, Department of Agriculture is continuing its research in assessing these compounds as bird repellents (Don Mott, John Cummings, personal communication). Obviously, an effective bird repellent which is harmless to mammals and economical to use would be one of the most important developments in bird management.

Curb. Aluminum ammonium sulfate (Curb) has been tried as an avian repellent on a variety of crops in many regions of the world. Field results have been variable and inconsistent. The compound has been reported to impart a metallic flavor to treated grapes (Ewing et al. 1976). Preliminary tests by Ewing et al. (1976) indicated that house finches and starlings damaged significantly fewer treated grapes than untreated controls.

Miscellaneous Aversion Compounds. Three other aversion conditioning agents have been used to protect seeds and seedlings from bird predators. Coal tar (62.7 percent) and Copper oxalate (4 percent) are registered as seed corn treatments for repelling crows. Lindane (25 percent plus 12.5 percent Captan) (the gamma isomer of benzene hexachloride) is registered as a seed treatment for corn, sorghum, and soybeans for deterring pheasants (Jacobs 1983).

Lachrymators. Tear gas has been tried as an avian repellent. The most widely used lachrymator is 2-chloroacetophenone (phenacyl chloride, Eastman Kodak Co.). Extensive testing of this compound as a potential nontoxic bird repellent was conducted with gulls, pigeons, and house sparrows (Vind 1969). This lachrymator was totally ineffective. Birds fed on seeds equivalently from panels coated with 5 or 10 percent solutions of this

compound and untreated control panels. Experimenters could not approach the treated panels downwind nearer than 0.3 m without feeling the effects of the lachrymator. Birds possess a second eyelid that is transparent (nictitating membrane), which closes in irritating environments. Predictably, birds should not be sensitive to lachrymators. However, walking sticks (Insecta, Orthoptera, Phasmatidea) possess a protective lachrymator related to catnip that is capable of causing ten minutes of temporary blindness and considerable discomfort in birds (Eisner 1965, Eisner and Meinwald 1966).

Frightening Agents

Acoustics

Introduction. A wide assortment of acoustical devices have been employed to disperse depradating, nuisance, or roosting birds (Hawthorne 1980). These devices fall into four categories in their order of importance: gas exploders, pyrotechnics, recorded alarm/distress calls, and electronic noise devices. Vendors for these products are listed in Appendix D. A very important consideration when using acoustics is that birds habituate quickly to any repetitious or consistent pattern of noise. Temporal and spatial variability must be incorporated into any acoustical bird management program. The best success has been achieved using a combination of scaring techniques, and scaring techniques are most effective when birds are new arrivals in an area (Hoy 1988).

Gas Exploders. Gas-powered exploders have saved more ripening corn from bird depredations than any other means (Besser 1985). Automatic portable propane exploders (or guns) can be left unattended and are designed with adjustable unequal firing intervals. Solar cells shut off the units at night and again turn them on in the morning. The noise from a propane discharge is about 10 times that of a shotgun blast. Acetylene or carbide models have also been used. Some models have adjustable barrel lengths to control sound levels. One model has twin barrels mounted on a bearing surface. The barrels fire in rapid succession and the blast from the recoil spins the barrels to a new random direction. Propane exploders are relocated at weekly (or less) intervals. The Razzo® (Margo Supplies Ltd.) is a vertically mounted propane gun which sends a "metal butterfly" to the top of a 7.5 m pole to add a visual effect. Gas exploders should be mounted on a stand just above the crop. A small steel drum with the ends removed positioned just beyond the barrel of the exploder amplifies the sound, increasing its effectiveness (Besser 1985). Each exploder fully protects 4 ha, but actually benefits a much larger area (Mitchell and Linehan 1967).

Conover (1984b) concluded that of the three methods being evaluated for reducing blackbird damage to field corn (Avitrol®, hawk-kites, and exploders), exploders were the most cost-effective, and they reduced damage by 72 percent. They required little labor, and a single exploder was sufficient to protect an area exceeding 100 m. See the following section on pyrotechnics for the problems and hazards associated with using explosive noises to disperse birds.

Pyrotechnics. An older and cheaper, but more limited way to make a great deal of noise is the use of pyrotechnics. A wide variety of agricultural explosive devices (fireworks) have been used: silver salutes, M-80s, cherry bombs, and rope firecrackers. The latter consist of large firecrackers strung together by their fuses being inserted through 8 to 9.5 mm cotton rope. The burning speed of the rope is increased by overnight soaking in an aqueous 8 percent solution of potassium nitrate (saltpeter) and allowing it to dry (Booth 1983). The timing of the explosions can be adjusted easily by varying the

distance between the firecrackers inserted into the rope. Special precautions must be taken with this technique because of its serious fire hazard.

Other commonly used pyrotechnics are devices that are fired as projectiles into the air by a 12 ga shotgun or a modified .22 pistol. Air explosions appear to be more effective than ground ones in frightening birds. Shellcrackers are fired from a 12 ga shotgun and explode 60 to 120 m away. Bird bombs, racket bombs, hissing rockets, noise rockets, whistle bombs, etc. are all pyrotechnics propelled by blanks fired from a modified .22 pistol. The firing range is 30 to 120 m depending on particular models. The exploding types are more effective than whistling noise models (Booth 1983).

Exploders and pyrotechnic devices have proved to be very effective, particularly when they are moved every few days and explosive intervals are varied. Explosive devices are probably most effective when used in conjunction with other avian management strategies. These devices have several important shortcomings. High noise levels, especially explosive sounds, are unacceptable in many environments: urban-suburban areas, airports, and recreational areas. The optimal time to disperse feeding or roosting flocks is early morning or evening--the times of the day when noise pollution is least appreciated. Another important consideration is the fire hazards associated with using explosive devices. This is particularly true with pyrotechnics, especially when slow burning long primary fuses are involved. Special precautions must be taken and safety criteria must be strictly adhered to when employing exploders or pyrotechnics.

Alarm/Distress Calls. Amplified recordings of alarm or distress calls have been used to disperse or frighten off birds (Frings and Jumber 1954, Pearson et al. 1967, Bremond et al. 1968, Lefebvre and Mott 1983, Schmidt and Johnson 1983). Alarm calls are given by birds to warn others of danger when a predator is sighted. Distress calls are given by birds when under physical stress (e.g., when seized by a predator) (Perrone and Paulson 1979). Not all bird species elicit both types of calls, some use a single call, and many possess neither call. Blackbirds, starlings, crows, and especially gulls are very responsive to these calls (Lefebvre and Mott 1983). Warning calls of a given bird species are not only interpreted by other individuals of that species but also by individuals of other bird species. Generally, these are related species, or species found in common association with one another. Some species that respond to warning calls of other birds do not themselves possess alarm or distress vocalizations. Possibly these species are responding to the flight behavior of alarm or distress calling birds (Brough 1968). Since these calls are natural, highly adaptive, and used frequently, birds should not habituate to them. However, birds gradually learn to recognize recorded calls, and that they do not represent danger (Blokpoel 1976). Gulls and crows can habituate to a recorded call in 6 to 8 days (Gramet and Hanoteau 1963).

Avian vocalizations are commercially available (Appendix D). The recordings are generally used on a good quality cassette tape recorder and broadcast through ordinary automotive or public address components. It is necessary to use high quality cassette tapes. Components should possess a frequency response of 250 to 12,000 Hz with an amplitude of 120 dB (1,000 Hz) at 1.2 m from the speaker (Boudreau 1971). Many birds (especially warblers) produce vocalizations at frequencies far above this range, but the only nuisance species of concern would be the horned lark. With these species, much more expensive hi-fidelity components would be necessary. If specific alarm/distress calls are not commercially available or if a specific local dialect is required, recordings will have to be made. This is a difficult and time-consuming task, but guidance is available (Bradley 1977, Fisher 1977, Simms 1979). An excellent discussion of the use of alarm/distress recordings can be found in Lefebvre and Mott (1983).

Electronic Noises. Electronically produced sounds by a sound generator are usually not as effective as alarm/distress calls (Booth 1983). Av-Alarm® is an automatic electronic device that produces very loud, variable, intermittent sounds (1,500 to 5,000 Hz). The noise is broadcast from a large speaker(s) mounted on a pole. Av-Alarm is powered by a regular 12 volt storage battery which lasts 4 to 6 weeks between recharges. Three different electronic sounds can be selected, incorporating three on and off time modes. Generally 8 to 12 seconds on and 25 seconds to several minutes off. The manufacturer claims this device to be effective to 200 m in a 90 to 120° sector, and swivel-lock extension speakers increase coverage up to 5 ha.

Johnson et al. (1985) found that a combination of sounds (white noise) was initially as effective as distress calls in frightening starlings. However, the birds habituated faster to the white noise than to distress calls. A pure tone did not elicit a fright response in starlings.

Ultrasonics. Ultrasonic sound devices are offered by several manufacturers. These products produce sounds above 20,000 Hz, which are inaudible to man. Some animals can hear higher frequencies than man (e.g., dogs, most bats, some insects), but most birds generally do not (Frings and Frings 1967). Ultrasonic sound devices have not been effective in frightening or dispersing birds (Lefebvre and Mott 1983, Don Mott and Ed Cleary, personal communication) and they have never been successful at removing birds from Air Force structures (Will 1985). However, Carl Cable (Chief, Construction - Operations Division, North Central Division, U.S. Army Corps of Engineers) has communicated an interesting report on the use of ultrasonics to control bird pests. In the mid-1950's the Dukane Corporation installed an Ionovac on Baltimore's City Hall to disperse the resident pigeon population. The device was operated above the canine hearing range at 115 dB. Nearly the entire bird population within a mile radius of the city hall, including pets, were exterminated.

Additional research is needed on the nature and interrelationships of sound combinations, acoustic variability, and avian habituation, in order to effectively and consistently repel or disperse depredating or nuisance bird flocks.

Lights

Flashing, rotating or strobe, and powerful searchlights have been used to frighten birds, with varying degrees of success (Lefebvre and Mott 1983). Amber lights timed to flash for five seconds at three minute intervals, combined with movable owl decoys dispersed a starling roost (Lefebvre and Mott 1983). Rotating beacon lights have not been successful in deterring pigeons, starlings, and house sparrows from roosting and nesting in Air Force hangars (Will 1985). Maintenance and the electric bill for the beacons was over $9,600 annually for a single Air Force base.

Reflecting Tape

Bird Scaring Reflecting Tape® has been used to protect agricultural crops from birds in Bangladesh, India, Japan, Philippines, United States, and other Asian and African countries (Bruggers et al. 1986, Dolbeer et al. 1986a). The tape is manufactured and distributed in Japan (see Bruggers et al. 1986 for sources). This tape consists of an elastic transparent synthetic resin film to which a silver metallic layer is vapor deposited, while the other side is coated with a colored (usually red) synthetic resin. It is 11-mm wide, 0.025-mm thick and comes in 82 or 100-m rolls. The tape is stretched across the field usually 0.5 to 1.0-m above the crop at 3 to 10-m intervals. The tape produces a flashing effect in sunlight, and when stretched it pulsates and produces a loud

humming or occasionally thunder-like noise in the wind. Because it is so thin, only slight breezes are necessary to give it action.

Reflecting tape reduced red-winged blackbird damage to millet, sweet corn, and sunflowers, and cowbird damage to millet in field trials in the United States (Dolbeer et al. 1986a). House sparrows were also excluded by the tape, but goldfinches and mourning doves were not. Bruggers et al. (1986) reported that preliminary investigations in many countries using reflecting tape showed reduced damage in a wide variety of crops attacked by a wide variety of bird species. The cost of the tape for use at 10-m intervals in a 1-ha field is \$4.68, \$0.36/82m (Bruggers et al. 1986).

The tape also prevented common crows from roosting and pecking holes in a flat roof in Ohio (Bruggers et al. 1986). In this case, 15 strips of 30-m each were stretched across the roof (100 x 30-m) at 7-m intervals.

However, the identical reflecting tape failed to protect blueberries from bird depredations at three localities studied in New York (Tobin et al. 1988). The researchers reported that the tape had no effect on the behavior of starlings, robins, house finches, mockingbirds, and catbirds.

Research is needed to evaluate this or similar inexpensive flashing tape for repelling pigeons, starlings, and house sparrows from roofs, ledges, locks and dams, bridges, structural supports in buildings, and other urban, commercial, and industrial sites. In order to optimize the frightening characteristics of the tape for different species and site-specific conditions, controlled experiments should be planned using different tape: width, thickness, reflectiveness, color, and material of construction. Strength, longevity, high and low temperature properties, and UV stability should be important considerations in tape design. In some difficult bird management situations, even high performance expensive tape may be more cost effective than inexpensive tape or other control methods. Although plastics and resins may pose disposal (e.g., landfill leaching, incineration) or littering problems, reflecting tapes cause fewer environmental hazards than toxins and other chemicals used in bird control.

Models

Predator. Predator models have been in use for a long time with varying degrees of success (perched owl models are probably the most familiar). Models are often ineffective, however, since birds habituate very quickly to them, especially if their spatial context does not change (Shalter 1978), or the model does not attack prey (Conover and Perito 1981). To be effective, the models must often be relocated. Suspending the models from wire or nylon monofilament line so that they move with wind currents makes them much more effective than stationary models. Crows mob a predator more intensely when it has killed or is holding a crow (Barash 1976, Denson 1979).

Conover (1985a) demonstrated in field experiments that the placement of a plastic owl model on a weather vane to increase its mobility and the addition of an animated struggling crow model to the talons of the owl model was an effective deterrent to crows in tomato and cantaloupe plots. An identical but stationary owl model was totally ineffective, since crow damage was similar in both treatment and control plots. The crow-killing owl models were inexpensive and easy to construct. An identical battery-powered animated model produced comparable results to the wind-powered model and would offer crop protection during calm weather, but was more expensive and difficult to build.

Models of soaring hawks, falcons or eagles have been used to frighten birds (Hothem and DeHaven 1982). The models can be attached to helium-filled balloons or tall poles. Birds habituate much less to hawk-kite models than to other disturbing objects (Conover 1979).

Conover (1982) demonstrated that although the hawk-kite model was somewhat less effective than netting or methiocarb for protecting blueberries from a wide variety of bird species, it was much cheaper, did away with the time interval required between spraying and harvest, and was a control method approved by consumers. Consumer concern about chemical residues is a particularly important consideration for fruit growers who mainly rely on customer harvesting.

Hawk-kites were also successful and cost-effective in reducing blackbird damage to field corn (Conover 1984b). The kites were the most successful technique evaluated in reducing bird damage in their immediate vicinity, reducing damage by 83 percent. The main drawbacks of hawk-kites with balloons is their cost, high labor requirements, and vulnerability to weather and vandalism.

<u>Bird Corpses</u>. The display of dead-bird carcasses has been successfully used to repel some bird species, especially gulls and crows (Lefebvre and Mott 1983). Plastic or fiberglass models can also be used, if they are accurate replicas and made to look like corpses, but there are no commercial sources (Lefebvre and Mott 1983). Stuffed, taxidermally-prepared specimens and formalin-preserved specimens have been used successfully at airport runways, but they lacked longevity (Blokpoel 1976).

<u>Scarecrows</u>. Scarecrows are one of the oldest bird control devices and can sometimes be highly effective. At least one scarecrow is needed per 4 to 6 ha, and they should be moved every 2 to 3 days since birds will habituate to them (Hawthorne 1980). They can be constructed from almost any material, but an important consideration in the design is that there are components that move or swing with the wind. An electrically powered mechanical version is available which periodically rotates its head and arms while an air horn sounds (Lefebvre and Mott 1983).

<u>Predators</u>. The use of predators to frighten off or kill bird pests has not been given adequate consideration. The British and Canadian Air Forces use live falcons to control birds at their airports (Blokpoel 1976). Harris' hawks (*Parabuteo unicinctus*) are being evaluated to frighten birds from Kansas cattle feedlots (Lee 1988). Falcons, goshawks, and Cooper's hawks have been used to disperse local concentrations of small roosting flocks of blackbirds, starlings, or crows (personal observation). The reintroduction of peregrin falcons to skyscraper habitats has reduced local populations of pigeons. Four of 16 territorial pairs of peregrines in the eastern United States in 1983 nested on bridges (Temple 1985). Most peregrine falcons reestablished in eastern United States have adopted manmade structures as nesting sites (Temple 1985).

Birds rapidly recognize and are easily frightened off by falcons and accipiter hawks (see footnote on p 21), since these are fast, highly maneuverable species that include birds in their diet.* Buteo hawks are the familiar and abundant fan-tailed soaring hawks. These species feed by swooping down on small mammals and occasionally snakes and lizards. Anatomically these species are designed for efficient soaring, not high-

*Kestrels (a falcon) mainly feed on large insects, but small mammals, lizards, and small birds are also taken. Kestrels nesting in urban areas feed on house sparrows when they are abundant (personal observation).

speed maneuvers. Individual birds and flocks, especially blackbirds and crows, often attack and mob buteo hawks. Although they generate excitement, buteo hawks are not as effective as falcons and accipiters for frightening birds.

Owls mainly feed on small mammals, although great horned owls have a very broad diet, including birds. However, owls are not easily trained. Eagles are large and difficult to manage. The golden eagle mainly feeds on small and medium sized mammals, while the bald eagle is primarily piscivorous and a scavenger.

Chemical

4-Aminopyridine. 4-Aminopyridine (4-AP), Avitrol®, or FC corn chops-99S (Avitrol Corporation) was developed in the 1960's for protecting field corn from depredating blackbirds (DeGrazio et al. 1971, 1972, Stickley et al. 1972, 1976b). Avitrol is generally used as a cracked corn bait containing 3 percent or 0.3 percent by weight of 4-aminopyridine (Phillips Petroleum). It is blended with cracked corn (1:99 or 1:9 respectively) so that one out of a hundred particles contain 4-AP, when it is used in agricultural fields as a frightening agent. Therefore, the final concentration is 0.03 percent (Avitrol label). Avitrol formulations are available with varying bait carriers and concentrations of 4-AP (Don Mott, personal communication). When used as a frightening agent, the application rate of the final bait (0.03 percent) is 1.1 kg/ha (33g/ha of 4-AP) applied to the total area (Besser 1985). Avitrol is generally applied in swaths to only one-third (Kelly and Dolbeer 1984) or one-ninth of the field (Besser and DeGrazio 1985). Therefore, concentrations in the swaths would be 3.3 kg/ha and 9.9 kg/ha, respectively. The usual distribution strategy is two to five applications, each applied every four to seven days during the milk and dough stages of kernel development (Kelly and Dolbeer 1984, Avitrol label).

Upon ingestion of 4-AP, blackbirds elicit strong distress and alarm behavior before death, which repels or frightens other members of the flock (Goodhue and Baumgartner 1965). The distress behavior consists of squawking and alarm calls, erratic flight, tremors and convulsions. This behavior has been reported in red-winged blackbirds, grackles, starlings, and house sparrows (Goodhue and Baumgartner, 1965). The effective use of Avitrol, therefore, requires the presence of a large number of flocking birds, with a sufficient proportion ingesting the treated bait over a short time span so that the flocks are dispersed before extensive crop damage occurs. A decided advantage of Avitrol is that less than 1 percent of the visiting flock is killed and there are minimal hazards to nontarget species (DeGrazio et al. 1972, Knittle et al. 1976, Mott 1976).

Avitrol has not been effective with low to moderate agricultural bird pressure (Dolbeer et al. 1976, Stickley et al. 1976b). The use of Avitrol was highest during the initial years after registration, but its use has rapidly declined throughout the 1970's, based on a survey conducted in Ohio, Michigan and New York (Kelly and Dolbeer 1984). This trend was particularly strong in Ohio and Michigan, even though the former state has an extensive history of agricultural nuisance bird problems. The cost of Avitrol increased by 84 percent between 1972 and 1982, but the cost of Avitrol per hectare relative to the mean cash value of corn per hectare remained about the same (Kelly and Dolbeer 1984). Blackbird populations in these three states declined during the 1970's (Dolbeer and Stehn, unpublished report, in Kelly and Dolbeer 1984), and Dolbeer (1981) estimated that in order for Avitrol to be cost effective a farmer must lose more than 5 percent of his crop. However, surveys throughout Ohio indicated that only about 1 percent of the cornfields received this level of damage (Kelly et al. 1982). Dolbeer (1981) reviewed blackbird damage to corn in five states and Ontario, and in most

instances less than 1 percent of the crop was lost. Conover (1984b) similarly reported that Avitrol was not generally cost effective.

Many Ohio farmers have been dissatisfied with the performance of Avitrol, but delays in application or improper use are critical detriments to its effectiveness (Stickley et al. 1976b, Woronecki et al. 1979). Blackbirds do their damage in a short time span, when the kernels are in the milk stage of development (Bridgeland 1979). Harris (1983) reported that Avitrol performed poorly in 1982 field trials in Manitoba. The Jaeger et al. (1983) study was inconclusive on the effectiveness of protecting ripening sunflower crops from blackbirds.

Additional problems with Avitrol have included crickets removing the bait, up to 95 percent in controlled experiments (Woronecki et al. 1979). Up to 80 percent of the initial 4-AP concentration has been lost through abrasion and up to 30 percent by sublimation when temperatures exceeded 24 °C (Kelly and Dolbeer 1984).

Avitrol has been used in Uruguayan corn fields with good initial success reported (Calvi et al. 1976). Monk parakeets (*Myiopsitta monachus*) were the chief offenders and displayed the typical distress or alarm behavior. A 95 percent reduction of monk parakeets in treated fields was reported. Other species to abandon the treated fields were eared doves (*Zenaida auriculata*) cowbirds (*Molothrus badius*), and brown and yellow marshbirds (*Pseudoleistes virescens*). Apparently, at the concentrations used, Avitrol was not toxic to monk parakeets. In this same study, Avitrol was not very effective with sunflower crops because the birds hulled the seed before ingestion; therefore, receiving very little of the toxin. Calvi et al. (1976) recommended that methods be developed that enable the compound to adhere more strongly to the bait.

Avitrol was used in Sudan to attract a wide variety of bird species to treated millet bait stations and away from wheat fields (Martin 1976). Although the birds did not respond with typical alarm calls or distress behavior and flocks were not dispersed, Avitrol did induce an aversion to the bait sites, causing the birds to shift their foraging areas. In order to protect a large wheat field, Martin (1976) surmised that the bait would have to be broadcast over large areas.

The addition of hydrochloric acid, forming the hydrochloride derivative, appreciably stabilizes Avitrol during storage and at high temperatures. This increased stability, the addition of insecticides to prevent bait removal by insects, and the use of small bait particle sizes (e.g., 11 mg) have enabled Besser and DeGrazio (1985) to successfully and cost effectively repel depredating blackbirds. Their technique greatly improved the benefit/cost ratio. However, tests in Canada using the hydrochloride derivatives were inconclusive (Harris 1983).

Successful Avitrol use has been reported for sweet corn in Wisconsin (Knittle et al. 1976) and Idaho (Mott 1976) and for sunflowers in the Dakotas and Minnesota (Besser and Guarino 1976, Besser 1985). At higher concentrations Avitrol is used as an oral toxin (see *Oral Toxins*, p 74).

Toxins

Introduction

The use of toxins, either oral or contact, can be an effective means of eliminating persistent bird pests. They are often used as a last resort when other methods have failed. It must be emphasized that the use of toxins requires a number of important considerations: (1) the toxin must only be used for the specific species and uses for which it is registered, (2) the manufacturer's instructions and safety precautions must be closely followed, (3) the application should be performed by experienced personnel, usually Federal or State animal damage control experts* or commercial pest control operators, (4) toxins should be used when relatively small numbers of birds are involved, and (5) a careful monitoring program must be implemented to assess the hazards to nontarget species, secondary toxicity, and any potential environmental impacts or contaminations. Secondary toxicity results from predators or scavengers feeding on erratically behaving, dying, or dead birds. Erratic behavior, distress calls, and birds in physiological stress attract predators. Scavengers and predators are also typically attracted to large numbers of bird carcasses, where they gorge themselves. Starlicide® is much less hazardous than typical toxins (see Starlicide®, page 75).

Toxins that are persistent in the environment (e.g., chlorinated hydrocarbons such as DDT, endrin, aldrin, dieldrin, chlordane, and their relatives) should not be used because they accumulate geometrically up food chains. Appendix F summarizes nationally registered bird control chemicals, and Appendix E gives chemical nomenclature.

Prebaiting

Prebaiting is not only an essential step in achieving maximum bait acceptance by the majority of target individuals, but enables the pest manager to assess any potential hazards with nontarget species. Prebaiting is the consistent placement of untreated bait in appropriate troughs or trays in the same location and with the same type of bait for several days to 2 weeks. The location should be acceptable and convenient for the target species but unavailable to nontarget species (e.g., most sparrow species prefer or will only feed at ground level and pigeons need large flat surfaces). The prebaiting period concentrates the birds and gives them confidence in the bait, containers, locality, etc. If the treated bait were introduced immediately, only a few individuals would be affected since their reaction to the toxin would discourage others from feeding on the bait.

Oral Toxins

Strychnine. Strychnine (see Appendix E for chemical nomenclature) is a highly toxic alkaloid processed from the dried ripe seeds of *Strychnos nux vomica*, a small tree native to southern Asia and northern Australia. Strychnine is a neurotoxin that must be taken orally to be effective. Lethal doses are species specific, and also depend on body weight and physical condition. The LD_{50} for birds is usually between 3 to 25 mg/kg, depending on species. Some common LD_{50}'s are: mallard (2.9), house sparrow (4.0 to 8.0), pigeon (21.3), and ring-necked pheasant (24.7). Most mammals generally fall within this same range, but strychnine is especially toxic to dogs, cats, coyotes, and kit foxes

*Appendix C gives the names, addresses, and telephone numbers of all the current state directors of the Animal Damage Control Section of the U.S. Department of Agriculture.

(0.7 to 1.2) (Timm 1983b). On the basis of LD_{50}, the amount of strychnine needed to kill a 400 g pigeon is about the same needed to kill a 11 kg dog.

Strychnine baits (0.6 percent) are only registered for pigeons and house sparrows around farm buildings and municipalities (Jacobs 1983). Strychnine was used in a carefully planned program to eliminate pigeons from a large area of downtown Kansas City, Missouri (Franke 1983), and at industrial sites (LeBlanc 1988). Because of its toxicity, strychnine is very effective but nonspecific. A bird with an empty crop feeding in the morning on toxic bait will die in 5 to 10 minutes. Strychnine, although biodegradable, poses toxicity hazards for nontarget species, humans, pets, and scavengers. For a scavenger to be affected it must consume the entire carcass, since strychnine will be present in the gut and not in muscle tissues (Cleary 1988). It should only be used as a last resort in very limited or small areas where there is minimal danger to nontarget species or secondary consumers. Human consumption of a lethal dose of strychnine is unlikely because of its bad taste and the high dosage required compared to concentrations present in toxic baits (Ed Cleary, personal communication). A prebaiting period is used with strychnine. The future of strychnine as a toxin for bird control is uncertain, since it will probably be withdrawn from Federal registration (Franke 1983).

4-Aminopyridine. Avitrol® is available as a whole kernel or cracked corn bait containing 0.5 percent of the active ingredient, 4-aminopyridine (4-AP). Dilutions of 1:4 or 1:9 treated bait to corn are usually used with equal success. These concentrations are registered for common pigeons, house sparrows, European starlings, blackbirds (red-winged, yellow-headed, Brewer's, and rusty), grackles, cowbirds, crows, and gulls for use on or in the area of structures and feeding, nesting, loafing, and roosting sites (Cleary 1988). A prebaiting period should be used with 4-AP treated baits.

Birds are generally more sensitive to 4-AP toxicity than mammals. Most birds possess an $LD_{50} < 10$mg/kg, and death occurs in 15 minutes to 4 hours (Timm 1983b). A cat apparently remained healthy after a 4-day period in which it was fed 51 sparrows that were killed with 19 times the lethal dose of 4-AP (Timm 1983b).

Low concentrations of 4-AP are often used so that pest birds can disperse before dying, thereby avoiding public reactions to a toxicity program. Dilutions of 1:19 or 1:29 have been successful in eliminating large flocks of pigeons with few visible carcasses (Mampe 1976). However, it takes longer to achieve control when lower concentrations are used (Courtsal 1983). The duration of treatment to eliminate a particular bird problem is highly variable depending on the magnitude of the problem, bird species, season of the year, bait placement, success of the prebaiting schedule, and other site-specific conditions.

Avitrol is also available in 25 or 50 percent concentrated powder to be mixed with site-specific baits in controlling starlings in feedlots or gulls in landfills or roosting/nesting sites (Jacobs 1983).

Starlicide®. Starlicide, also known as DRC-1339, is the trade name of a slow-acting toxicant developed by Ralston Purina Co. It consists of food pellets containing 1 or 0.1 percent 3-chloro-p-toluidine hydrochloride. Starlicide is also available in concentrated form (98 percent purity) for treating user-specific baits, but a permit is necessary to acquire the compound (Doug Hall, personal communication). Starlicide is registered for use against European starlings and blackbirds around livestock feedlots and poultry operations. DRC-1339 Gull Toxicant is registered for the control of herring gulls and great black-backed gulls in breeding colonies of terns, puffins, laughing gulls, and other colonial nesting seabirds within coastal northeastern United States (Cleary 1988).

Special Local Need Registrations (SLN 24-C) are necessary for using DRC-1339 for roosting blackbirds, starlings and crows, or pigeons in urban areas (Cleary 1988).

Starlicide has most commonly been used to control starlings (the most serious bird pest) and blackbirds at cattle and hog feedlots and dairy and chicken farms (Besser et al. 1967, Royall et al. 1967, West et al. 1967, West 1968, West and Besser 1976, Stickley 1979). The normal application rate is 0.5 kg of Starlicide pellets (1 percent concentration) per metric ton (1 lb/ton) of livestock ration (West and Besser 1976), which results in an overall concentration of 5 ppm of active toxin. This concentration is highly toxic to starlings, blackbirds, and crows, and ingestion of a single pellet is fatal. Higher concentrations of the toxin are unnecessary. Death usually occurs within 5 to 24 hours, but never less than 3 hours (even at very high concentrations), and some individuals take up to 3 days to succumb (West and Besser 1976, Timm 1983b).

Glahn (1982) recommended the use of bait containers to attract foraging starlings. A prebaiting period using untreated bait was considered essential to attract the starlings to bait containers strategically located in the feed lot. By this method starlings were fed a more concentrated diet of the toxin, the total amount of Starlicide was reduced, and livestock did not ingest any of the material. This method produced mixed results. The location and numbers of bait containers was important. Also, the prebaiting period using untreated bait was critical, so this method was more management/labor intensive.

Starlicide is also used as bait (0.1 percent) scattered lightly around pens and alleyways in livestock and poultry feedlots (10 to 55 kg/ha, depending on the size of the feedlot operation--higher concentrations are used in smaller feedlots) (Starlicide label).

Starlicide exhibits a much lower toxicity to mammals than to birds; however, cats are sensitive (Don Mott, personal communication). Bird species vary widely in their susceptibility to Starlicide; starlings, blackbirds, crows, turkeys, and owls are very sensitive, but some hawks and sparrows show a low toxicity to the compound (Decino et al. 1966, Don Mott, personal communication). Pheasants, ducks, doves, and pigeons are moderately sensitive. Pigeons are about four times less sensitive to Starlicide than starlings. Appendix G gives the LD_{50} doses for selected bird and mammal species. Therefore, nontarget species feeding on the bait may vary considerably in their susceptibility to the toxin. Since a prebaiting period is necessary with DRC-1339 baits, a monitoring program should assess the potential hazards to nontarget consumers.

Starlings completely metabolize the compound in 2.5 hours including the excretion of all metabolites (Timm 1983b). Since minimal survival time after ingestion is 3 hours even at very high doses, there can never be secondary consumption of DRC-1339 by scavengers or predators feeding on carcasses. Additionally, it is slow acting and the affected birds disperse before dying, an important consideration when avoiding publicity.

Rhoplex® AC-33 (Rhom and Haas Chemical Co.) is a compound sometimes used in conjunction with Starlicide. It masks the flavor of Starlicide so that late feeding arrivals of the flock are not diverted away by early feeders displaying aversion reactions. Additionally, it is also a sticking or adhesive agent, aiding the adhesion of the active toxin to the selected bait (Doug Hall, personal communication).

Hall (1985) presents an excellent example of using Starlicide in a user specific bait. Starlings were nesting within fiberglass and styrofoam insulation, creating extensive damage. The birds were foraging and feeding their nestlings with large quantities of dead june beetles found beneath night-lights. Crickets were purchased (readily available in bait and pet shops) and killed by hot water immersion. The cricket

carcasses were treated with 1 g of Starlicide (98 percent concentration) dissolved in 10 ml of warm water and 5 ml of Rhoplex AC-33 solution (5.7 mg of active compound per cricket). Therefore, a single cricket contained a lethal dose for starlings (see Appendix G). The bait was placed under the night-lights early in the morning at a rate of five untreated crickets to one treated cricket. The nesting starlings were eliminated in two weeks.

The concentrated compound (98 percent) has also been added to french-fried potatoes and a variety of fruit to successfully control starlings (Johnson and Glahn 1983). Starlicide has also been used for blackbirds, crows, and pheasants at a rate of 1 percent active compound on cracked corn (Doug Hall, personal communication).

CAT. Peoples et al. (1976) recommended the use of a derivative of Starlicide known as CAT (2-chloro-4-acetotoluidine) as a substitute for Starlicide. They used 120 g per ton of feed (132 ppm). Both compounds possess similar toxicity to starlings, but CAT possesses several significant advantages over its parent compound: it is even less toxic to birds of prey and mammals, it is more stable and possesses a longer shelf life, and it does not cause human skin irritations. The LD_{50} for starlings is 2.6 mg/kg. However, this compound is not registered for bird control and is unavailable (Don Mott, personal communication).

Contact Toxins/Toxic Perches

Contact toxins represent a variety of toxins that are absorbed through birds' feet. The usual method of application is through the use of toxic perches (e.g., Rid-A-Bird®), which dispenses the toxin (Jackson 1978). Rid-A-Bird perches are 1.3 cm diameter perforated metal tubes either 69 or 76 cm long. The company's flat perches are 3.8 cm wide by 61 cm long. The hollow perches are filled with a contact toxin that is wicked to the surface with the wick running the outside length of the perch. For outdoor installation, the wick is covered with fine wire mesh to minimize dilution from rain. Fenthion (11 percent solution in oil) is the usual toxin, but endrin (9.4 percent solution in oil) has also been used.

The placement and number of perches deployed depend on site specific variables and the nature and magnitude of the problem. It is very important that the birds are surveyed, and their habits carefully observed before any perches are installed, in order to optimize perch placement and potential effects on nontarget species. Most failures of toxic perch programs are due to inappropriate perch locations. Usually 10 to 12 perches are required, but 30 or more will be necessary for large jobs (Martin and Martin 1982, Courtsal 1983). In general, if perches are carefully located, a density of one perch for 200 to 400 m^2 is sufficient.

Fenthion is much more toxic to birds than to mammals (Timm 1983b). Originally developed as an insecticide, it is an organophosphate, inhibiting acetylcholinesterase at nerve synapses. Mortality usually occurs from 3 to 72 hours after the birds have made contact with the toxin, depending on dose and species. Therefore, the dying birds may disperse over a wide area. Although organophosphates are not persistent in the environment, there is potentially serious danger of secondary toxicity to predators or scavengers. Birds affected with nervous system disorders from organophosphates represent easy targets for predators, which cue in rapidly on erratic behavior. Bruggers et al. (1989) conducted a study of secondary toxicity from Fenthion after spraying two nesting colonies of red-billed quelea in Kenya (see paragraph on ploceid weavers on p 64). The spraying caused massive mortalities to quelea and insects. Dead and dying birds from the larger colony sprayed (40 hectares) were found over an area of 3500 hectares.

Sixteen of 23 raptors examined in the area were apparently exposed to Fenthion based on cholinesterase depression. Bruggers et al. (1989) concluded that the use of Fenthion as an avicide presents lethal and sublethal threats to predatory and insectivorious birds.

Endrin's toxicity to birds is similar to Fenthion's but the former is much more toxic to mammals. Endrin is highly toxic to insects and fish and because of its persistence, is very detrimental when introduced into aquatic ecosystems. Endrin should not be used because of its environmental hazards (see Toxins, *Introduction*, p 74).

Toxic perches have been registered for *only* pigeons, starlings, and house sparrows, and are *only* to be used in the following areas: in and around farm buildings, pipe yards, loading docks, building tops, inside buildings and bridges (Rid-A-Bird label).

Toxic perches have been very effective in eliminating pigeons (also starlings and house sparrows) from aircraft hangars (Will 1985). Generally 37 to 61 perches per hangar have been adequate, taking several weeks to 2 months to completely eliminate hangar birds. In a Texas hangar containing about 1,000 birds, 40 perches eliminated 90 percent of the birds in 3 days. The use of toxic perches to eliminate pigeons in a California hangar had no effect on the resident population of 50 barn swallows. The cost per hangar of the Air Force program using Rid-A-Bird perches has been about 13 to 30 percent the cost of using netting (Will 1985). In other words, exclusion by netting was 3.5 to 7.5 times more expensive than toxic perches.

Other contact agents that produce harmful physiological effects when absorbed through a bird's feet have been patented: caffeine (1,3,7-trimethylxanthine), caffeine derivatives such as 1,3,7-triethylxanthine, lithium salts, amphetamine sulfate, amobarbital, procaineamide hydrochloride, phenmetrazine hydrochloride (3-methyl-2-phenylmorpholine), and trifluoperazine dihydrochloride (Kare 1972). Caffeine solutions proved equally lethal to all species tested (starlings, house sparrows, grackles, cowbirds) when absorbed through the feet. Except for amphetamine, all the above compounds proved to be similarly lethal in all the bird experiments. Amphetamine, when applied to the feed of cowbirds, drastically reduces food intake, which would be fatal under natural conditions. A large variety of solvents for the toxins were evaluated alone and in combinations (water, peanut oil, mineral oil, glycerine, dilute caustic and acid solutions, 70 percent ethanol, dimethyl sulfoxide). Despite widely varying solubilities (e.g., lithium carbonate was not very soluble in oils), the nature or compatibility of the solvent system with the toxicant made no practical difference to the lethal effects of the toxic substances. Apparently these compounds are highly lethal to birds, and much lower (even drastically lower) concentrations than those evaluated by Kare (1972) would be sufficient. These lower concentrations would be more economical, and the lower toxicity would disperse dying birds from the contact site. These compounds have yet to be used commercially or even in field trials, but are potential candidates for use in toxic perches or applications on the surface of specific bird loafing areas.

6 SPECIFIC PROBLEM MANAGEMENT

Introduction

This section makes specific recommendations for controlling species-specific bird problems. The methodologies are not discussed in detail and references are a minimum. Therefore, the reader must consult the appropriate sections in Chapter 5 (**Bird Management Strategies**) for specifics concerning specific bird management technologies. These recommendations are based on the extensive literature survey which forms the basis of this report.

Specific Species

Pigeons

Pigeons nest and roost on flat surfaces. A board or sheetmetal placed over a ledge at a 45° angle prevents pigeons from roosting, but the most effective, most permanent, and safest method to eliminate problems with nesting or roosting pigeons is by exclusion, using hardware cloth, poultry screening, or plastic screening or netting. However, this method is expensive when a large area is to be protected. In many instances, netting is impractical (e.g., lock and dam complexes). Bivings (1985) reported that plastic netting was the most effective solution for preventing pigeons from entering parking garages, empty buildings, and small aircraft hangars. Will (1985, personal communication) also found that plastic netting was very effective for eliminating pigeons from aircraft hangars. Pratt (1983) discusses methods for installing netting in aircraft hangars. See Appendix D for names of plastic screening/netting vendors.

Overhead monofilament lines do not exclude pigeons (Blokpoel and Tessier 1984), unless the lines are very closely spaced, making the technique impractical.

An effective way of keeping pigeons from landing on ledges, beams, girders, gutters, roof edges, and complex architectural structures is the use of porcupine wire (e.g., Nixalite and Cat Claw) or bird barrier. The practicality and cost of these wires generally limit their usefulness to relatively narrow surfaces (< 22 cm). They cannot be used to protect large surface areas, like roofs or bridges. An important consideration for many applications is that the product also prevents use of the protected surface by maintenance personnel. Although porcupine wire and bird barrier is expensive, they may be cost-effective since they may be effective and represent a permanent solution. Bivings (1985) reported Nixalite to be effective for deterring roosting pigeons, but expensive, and recommends it only if netting cannot be used.

Toxic baits, with an appropriate prebaiting program, have been very effective at controlling pigeon populations, particularly small scale problems. Bait is readily acceptable year-round since pigeons are primarily grain feeders. There are personal and environmental hazards when using toxins (see **Toxins**, *Introduction*, p 74). Whole corn bait treated with 4-Aminopyridine (Avitrol) or strychnine are usually the preferred toxins for pigeons, but Starlicide has been used and is usually less harmful to nontarget animals. Whole corn is generally too large to be accepted by small nontarget songbirds.

Western Industries (West Orange, New Jersey) has had a great deal of experience in pigeon control and primarily relies on Avitrol (Mampe 1976). They adjust the concentration in the bait to vary its level of toxicity. Mampe (1976) stresses the importance of prebaiting with untreated corn, generally for 2 weeks, to accustom the majority of the flock to accept the bait. After the prebaiting period, if quick results are desired (e.g., an industrial site off-limits to the public) a 4:1 or 9:1 ratio of corn to Avitrol is used as treated bait. This blend is highly toxic to pigeons, and results in many dead birds at the bait site. When downed birds are undesirable, such as in residential areas, a 29:1 ratio is commonly used after the prebaiting period, for about 2 weeks. This mixture has been successful in eliminating large flocks with few visible carcasses. Mampe recommends that the area be maintained with a 9:1 mixture to prevent flock buildup.

Plastic sandwich bags containing 112 g of Avitrol have been prepared for some pigeon control programs and tossed by hand into hard to reach areas: overhead beams, building ledges, etc. (Martin and Martin 1982, Courtsal 1983). Prebaiting with untreated corn in identical sandwich bags was considered essential.

Strychnine is an effective pigeon toxin (Dwight LeBlanc, Ed Cleary, personal communication) at industrial and commercial sites and is commonly used to exterminate pigeons when there is no danger to nontarget organisms. However, because of its toxicity to humans, pets, nontarget consumers, predators and scavengers, it must be used with extreme caution by licensed, experienced professionals in animal damage control.

Toxic flat perches (e.g., Rid-A-Bird), with proper placement, have been used successfully to eliminate pigeons from a variety of buildings. Environmentally, the safest place to use toxic perches is inside buildings. However, since death occurs 24 to 72 hours after the toxin is absorbed, birds may die some distance away. Therefore, toxic perches are hazardous to secondary consumers (predators or scavengers), particularly when a large bird-kill is involved.

Pigeons have been removed by grain baited live-traps placed on buildings. Since pigeons possess excellent homing ability, they are humanely disposed of after trapping. The walk-in bob trap is recommended for pigeons (Courtsal 1983), see Figure 1. Pigeon traps are large; the bob trap is 2.4 by 1.2 by 1.2 m and some traps are much larger. Pigeon traps usually contain caged live decoys. Live-trapping is not usually recommended for controlling pigeons, especially if large numbers or continued immigrations are involved, because the method is expensive and very labor intensive (Mampe 1976, Will 1985). However, with small local problems or where public opinion is critical, this may be a desirable method.

A relatively inexpensive technique that can be tried to deter roosting or nesting pigeons is the use of sticky repellents (e.g., Roost No More). These compounds are impractical to apply to large surface areas or to complex and inaccessible structures. Sticky repellents work best on narrow ledges or beams where the tacky strips are applied in parallel rows 7.6 cm apart and 1.25 cm from the edge on clean and dry surfaces. Repeated applications may be necessary. Sticky compounds have not been successful in controlling persistent pigeon problems (Mampe 1976, Will 1985).

Electrical shocking devices (e.g., Avi-Away), may keep pigeons from roosting on specific structures, but this method is generally impractical for most pigeon problems, since extensive surface areas generally need protection.

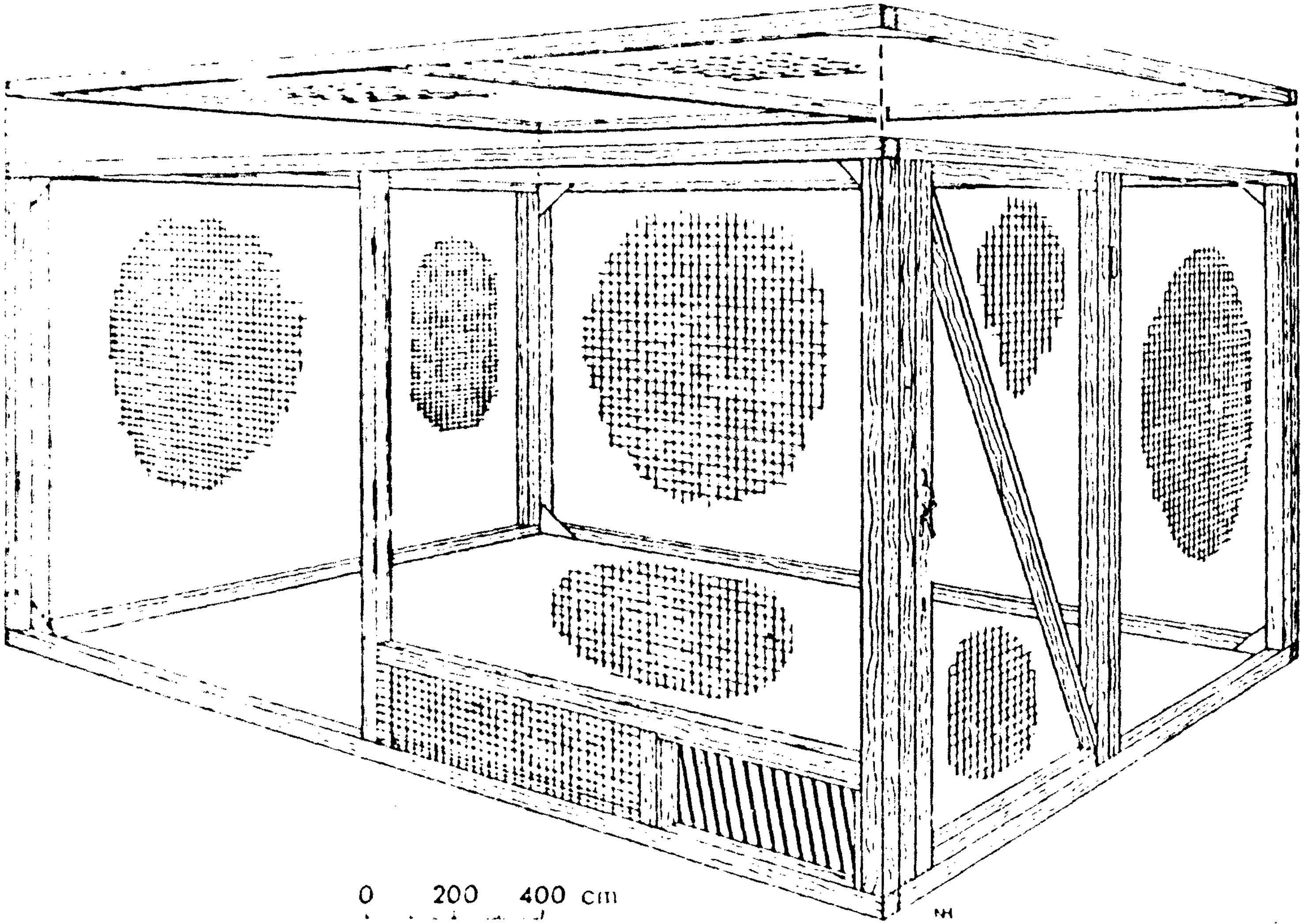

Figure 1. A bob trap for pigeons. (Lefebvre and Mott 1983, Courtsal 1983).

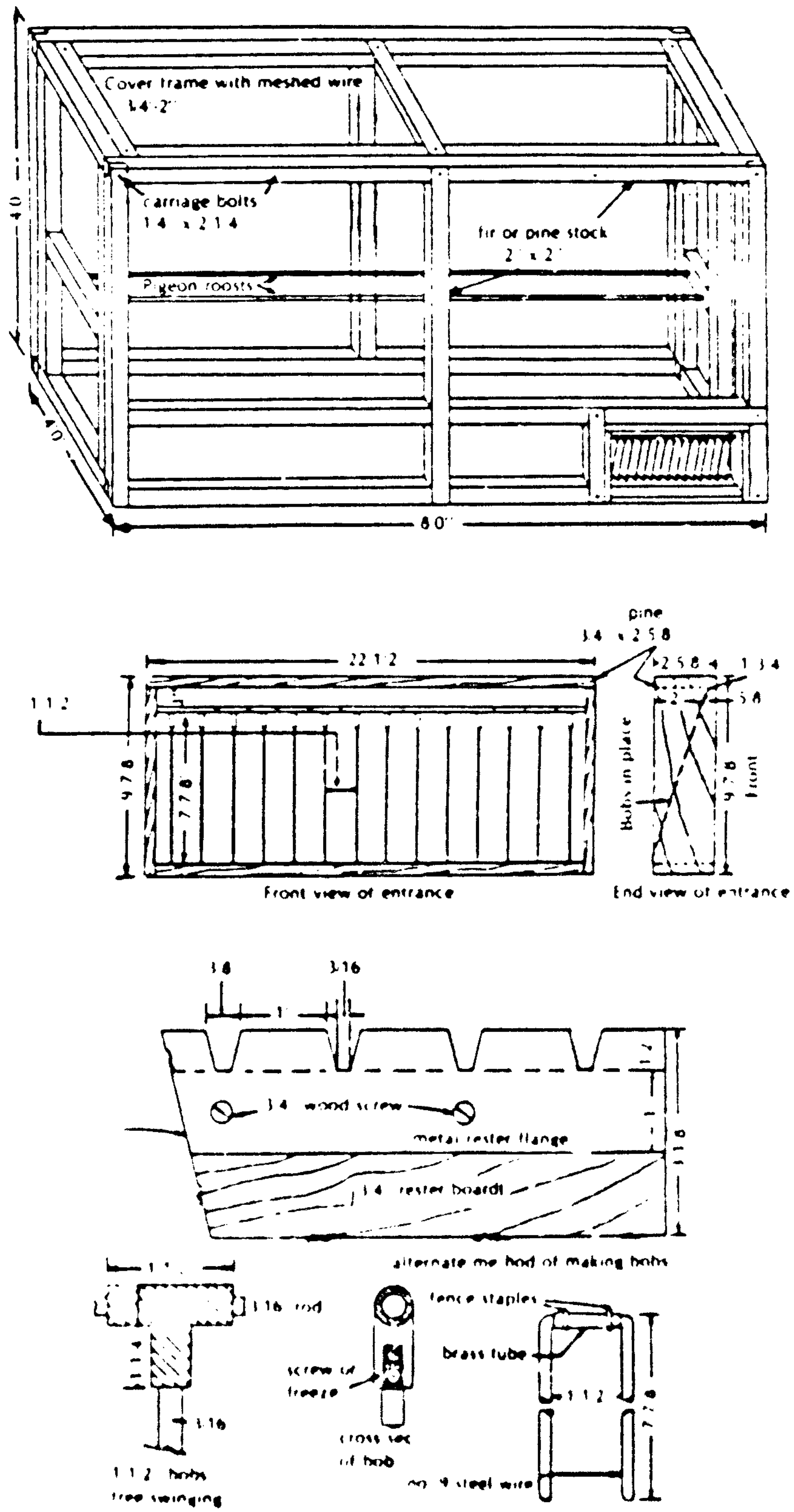

Figure 1. (Cont'd)

Chemosterilants have not been effective at controlling pigeon populations (Courtsal 1983, Erickson 1983).

An interesting and potentially very valuable experiment to control pigeon population would be to establish peregrine falcon eyries on bridges, skyscraper ledges, etc. Peregrines are usually cliff nesters, therefore utilizing a nesting habitat similar to pigeons. Peregrines are effective predators of pigeons, and have successfully nested and reared young on city buildings (Barclay and Cade 1983). Most peregrine falcons reestablished in the eastern United States have adopted manmade structures as nesting sites; about 25 percent of these are bridges (Temple 1985).

Starlings

Local roosting and nesting problems with starlings are similar to those caused by pigeons. Starling control strategies for the problems are therefore similar to those used for pigeons. Two important differences are that starlings are cavity or crevice nesters, and they may use round perches. Exclusion, porcupine wire, and sticky repellents have all been successfully used. Since starlings are smaller than pigeons, the spacing between rows of sticky strips should be decreased to 5 cm. A carefully designed experiment confirmed that naphthalene has no effect at repelling starlings (Dolbeer et al. 1988).

The most acceptable and appropriate toxin for starlings is Starlicide, used with a prebaiting schedule. Starlicide is in many ways an ideal toxin. It is very toxic to starlings, but possesses low toxicity to most mammals, at least some hawks and many other bird species. It is completely metabolized by starlings in 2.5 hours, and death never occurs before 3 hours, even at unusually high doses. Therefore, secondary toxicity hazards to predators and scavengers from carcasses is nonexistent.

Despite its seemingly "harmless" nature, applications of Starlicide, as is true of any toxin, should be done with extreme care and by trained personnel, particularly when a large-scale program is involved, and should include environmental monitoring.

Avitrol is as effective on starlings as it is on pigeons, but is probably more hazardous to nontarget organisms.

Toxic baiting programs may not be effective for starlings during warm months, and especially during the breeding season, since starlings at that time are highly insectivorous. However, starlings are very fond of fruit, and raisins, apples, and grapes, etc. have been used successfully as bait. Hall (1985) used Starlicide treated crickets to control nesting starlings (see p 76). French-fried potatoes have also been used successfully as a bait. Although toxic perches have been used successfully for starlings, Johnson and Glahn (1983) do not recommend their use because of secondary toxicity to predators or scavengers. The use of toxic perches should be restricted to small-scale problems within buildings or limited areas.

Frightening devices have had limited success in repelling starlings. Starlings respond very well to recorded alarm/distress calls, but eventually habituate even to these. They habituate more quickly to random electronic noises than to alarm/distress calls, but do not show a fright response to pure tones (Johnson et al. 1985). Gas exploders and pyrotechnics have successfully dispersed starlings.

Frightening devices may be of potential use in dispersing starlings, if used in conjunction with other methods. A very important consideration is that a combination of several scare devices works much better than a single technique, and maintaining

variability in noise frequency, amplitude, interval between blasts, and location of noise sources is essential to delay or even prevent habituation.

Live-trapping of starlings has been successful when other methods could not be used. Nest-box traps (Figure 2) are very effective, but only during the spring nesting season. Knittle and Guarino (1976) used 20 nest-box traps for starlings and captured 294 birds during 57 days of trapping on an 81 ha site in Colorado. Modified* Australian crow traps (Figure 3) (a decoy trap) are most effective when the birds are flocking from late summer through winter (Johnson and Glahn 1983). Decoy traps use one or more caged individuals of the target species, while grain or fruit bait is placed within the much larger decoy trap. Decoy traps have been effective in controlling starling populations in orchards (Ballard 1964) and urban areas (Stiles 1966). Funnel traps (Figure 4) have also been successful. The larger designs like Figure 4 are more effective than smaller traps. The size of openings in funnel traps is species specific, for obvious reasons. Trailers used to transport cotton have been modified to trap large numbers of starlings (Clark 1976). Additionally, the mobility was highly beneficial. Trapping starlings, as is true of other species, is very labor intensive, and takes a great deal of time. It may not be a feasible technique for large numbers of birds.

Starlings may be serious local pests at livestock and poultry feedlots. Twedt and Glahn (1982) recommended management methods to limit the availability of feed to birds depredating livestock pens. Most methods have proved inconvenient or too labor intensive to operators (e.g., daily opening and closing of feeding bin lids). Livestock feed could also be made into large pellet sizes which are unacceptable to birds (Mott 1984); this is a common practice in western feedlots (personal observation).

The usual starling (and blackbird) control technique at feedlots is the use of the toxin Starlicide. It is usually incorporated directly into the livestock feed. However, it has also been used in baited containers or as bait scattered on the ground between pens and walkways.

For the control of starling depredation of fruit crops or winter roosts, see **Fruit Crops**, p 102, or **Bird Roosts**, p 100.

House Sparrows

The control of house sparrows is in many ways similar to pigeon and starling control, but some important differences will be discussed. Often all three species will have to be dealt with together. As with pigeons and starlings, exclusion, porcupine wire, bird barrier, and sticky compounds are effective with minimal environmental damage. Since house sparrows are small birds, it is necessary to eliminate any openings over 2 cm for successful exclusion. Distances between strips of porcupine wire or beads of sticky compounds must also be proportionally shortened.

Strychnine and Avitrol treated baits are effective toxins for sparrows, and both have been used successfully. The best baits have been wheat, barley, oats, or cracked corn (Cleary 1988). Strychnine is used more frequently, but it poses personal and environmental hazards. Starlicide is not very toxic to sparrows. Toxic perches, when they are properly located, are very effective at eliminating sparrows, particularly in buildings. However, toxic perches are environmentally hazardous, particularly for predators and scavengers feeding on dying and dead birds.

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*Modified by reducing the opening sizes to accommodate species smaller than crows. Of course, the traps may also be made proportionally smaller.

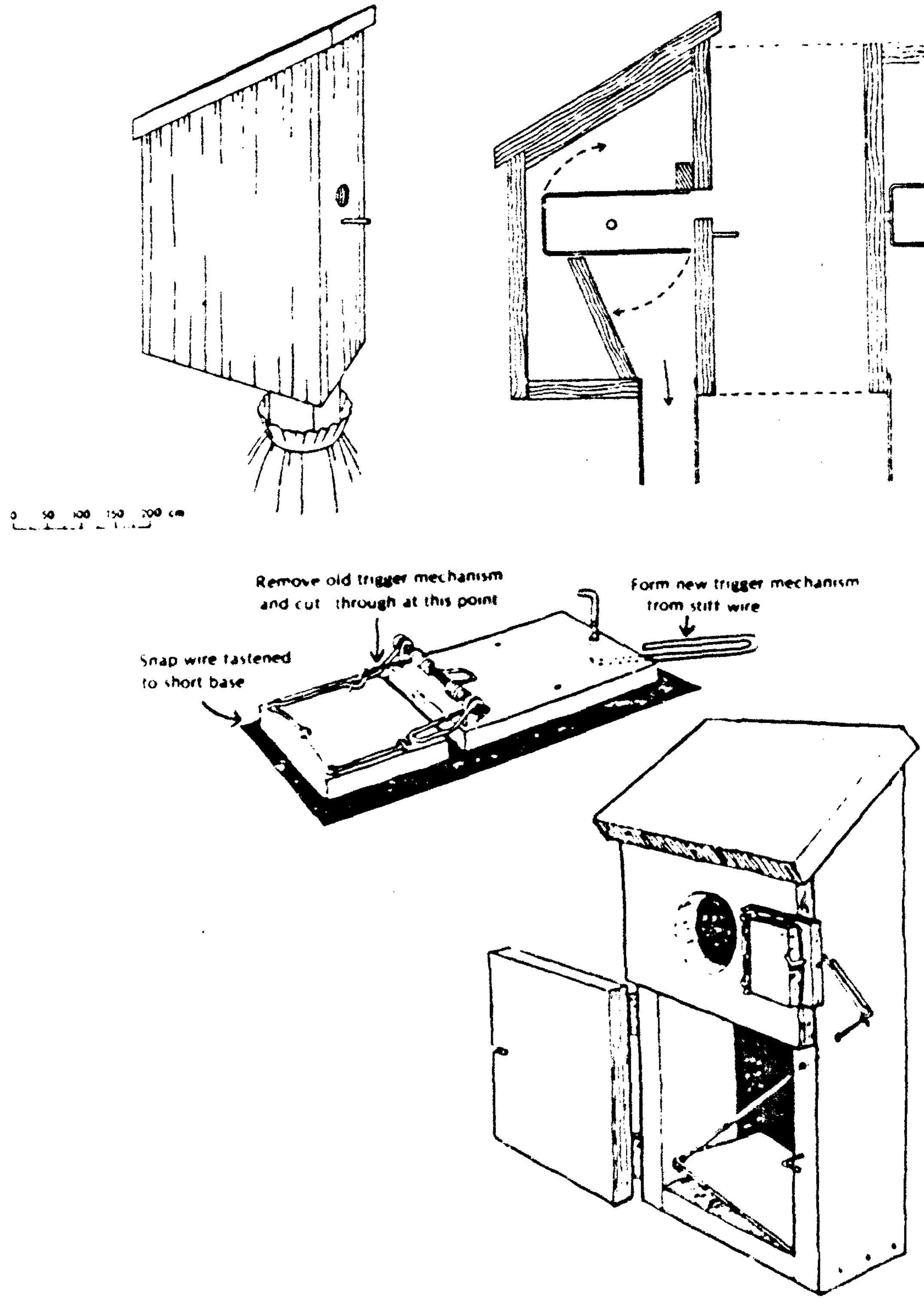

Figure 2. **Nest box traps for starlings or house sparrows. (A 2-bushel cloth bag is used for holding trapped birds in the Tesch trap.) Note that the nest box trap using a modified mouse trap only captures single individuals). (Lefebvre and Mott 1983, Johnson and Glahn 1983).**

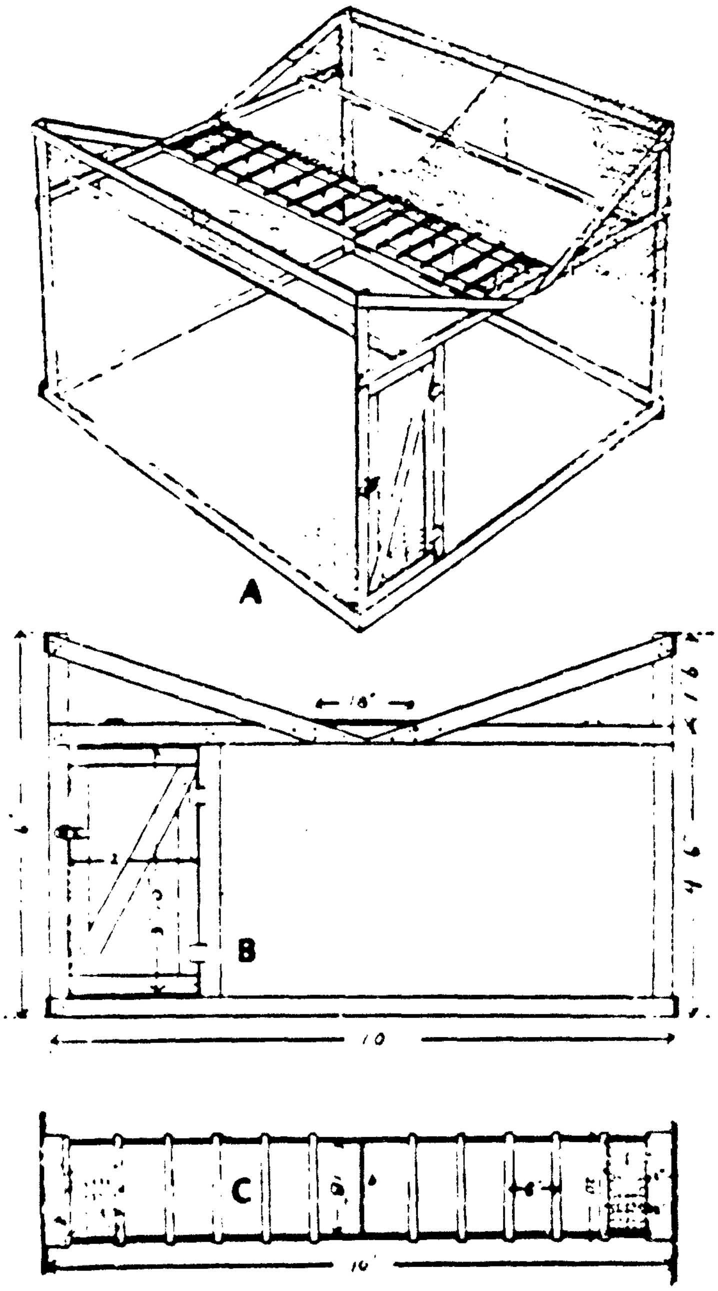

Figure 3. Australian crow trap. (A-completed trap, B-end view. C-plan of ladder opening.) (Johnson and Altman 1983, Johnson and Glahn 1983).

Materials Needed for Trap

15 pieces 1 x 4s 8 feet long
25 pieces 1 x 4s 6 feet long
4 pieces 1 x 1s 3 feet long

1 piece 1/2 x 16-in exterior plywood, 8 feet long
2 hinges
2 lbs staples
48-ft length of 6-ft chicken wire 1-inch mesh

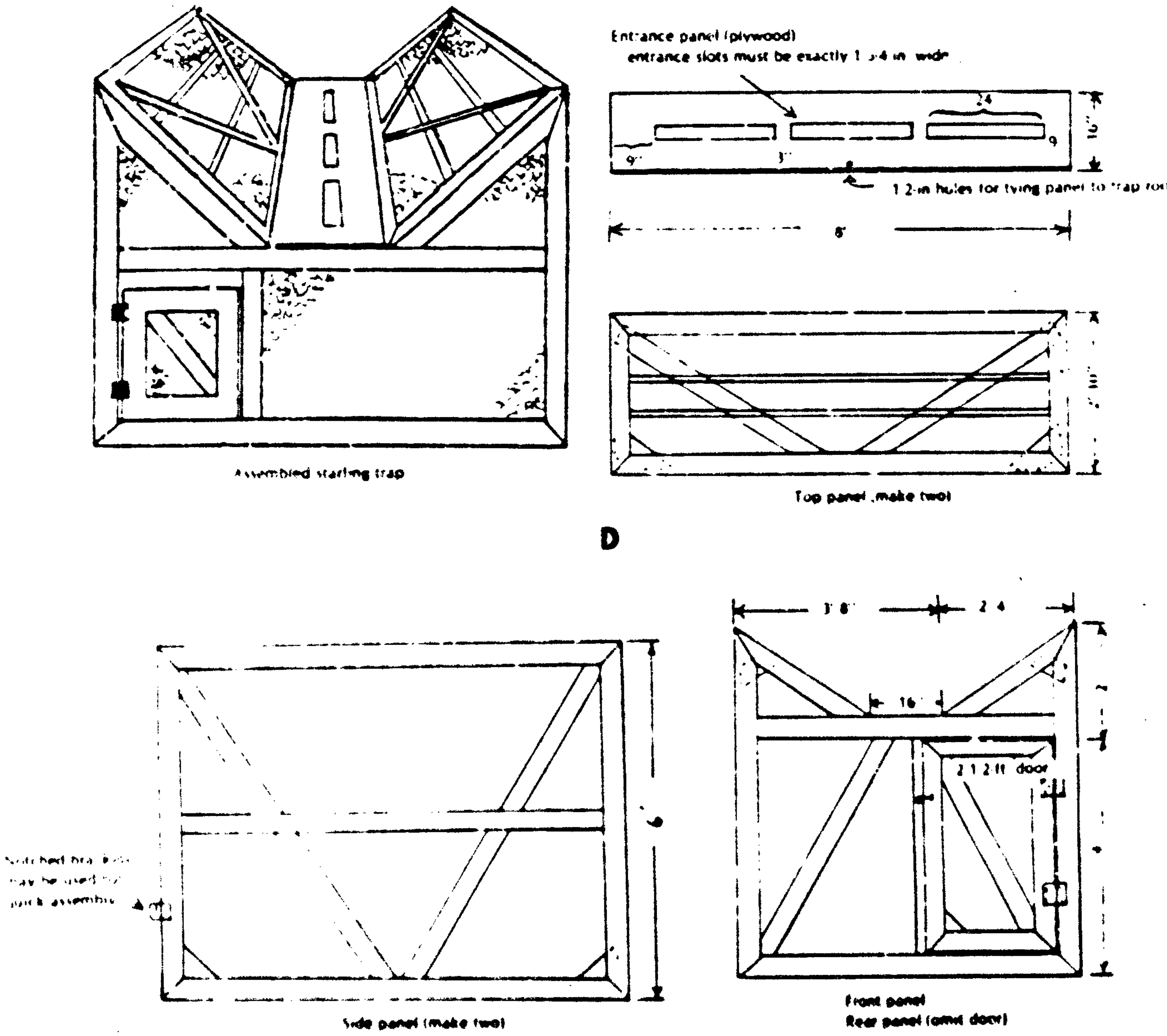

Figure 3. (Cont'd) (D-modified Australian crow trap for starlings.)

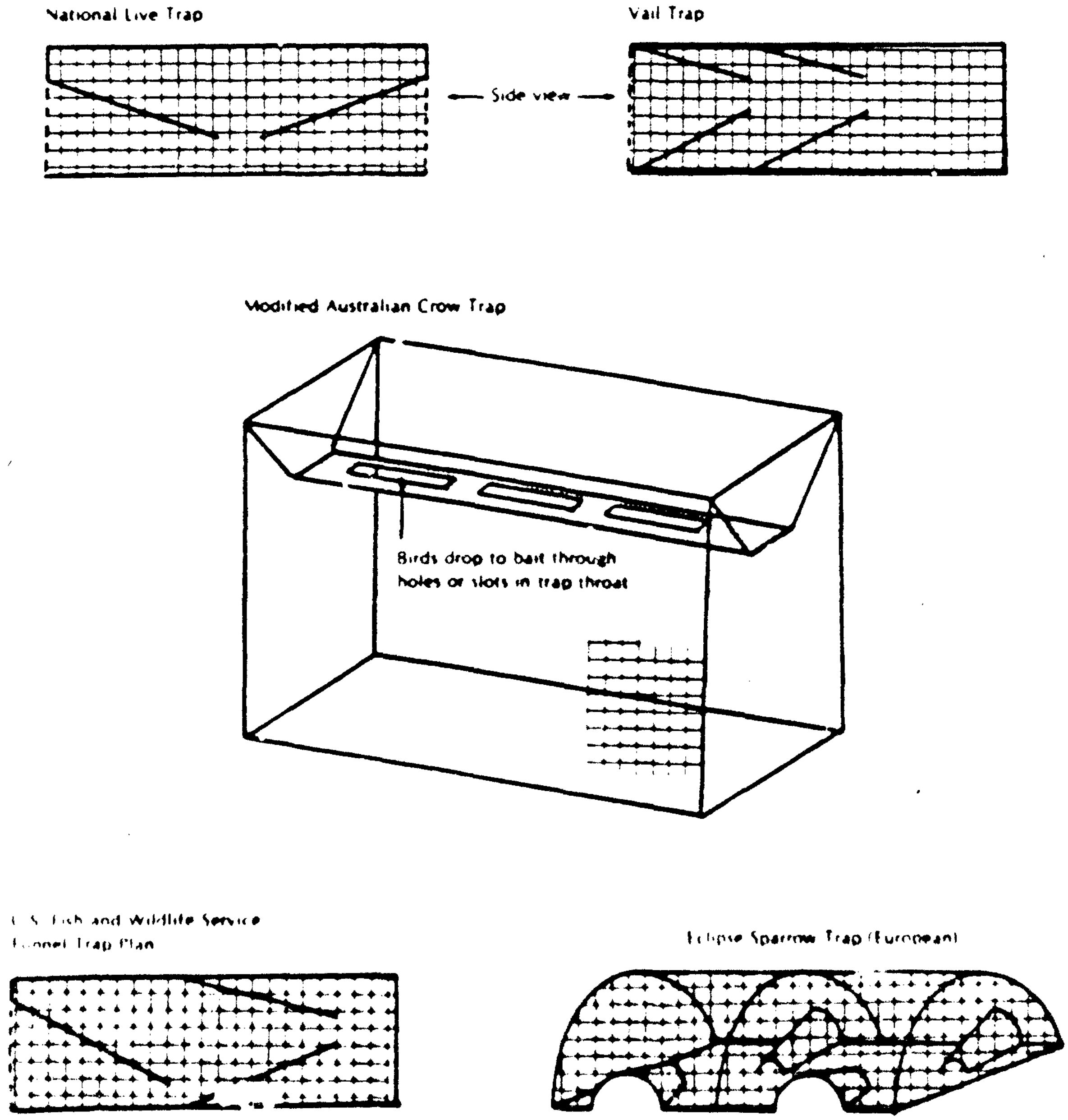

Figure 4. Funne traps. (A-miscellaneous designs) (Fitzwater 1983, Lefebvre and Mott 1983).

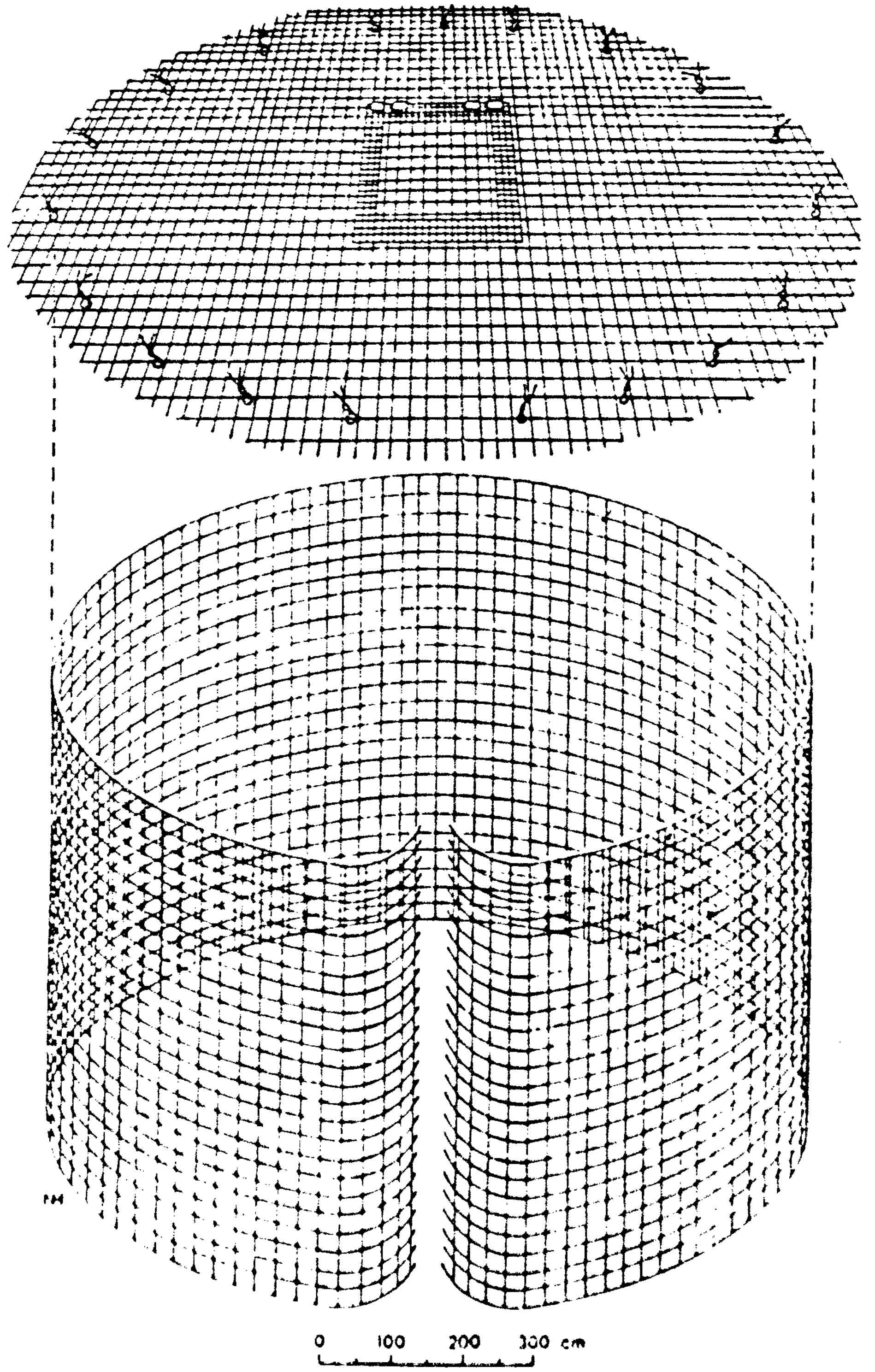

Figure 4. (Cont'd) (B-Lily pad trap effective for a variety of bird sizes—from sparrows to ducks—depending on width of entrance.)

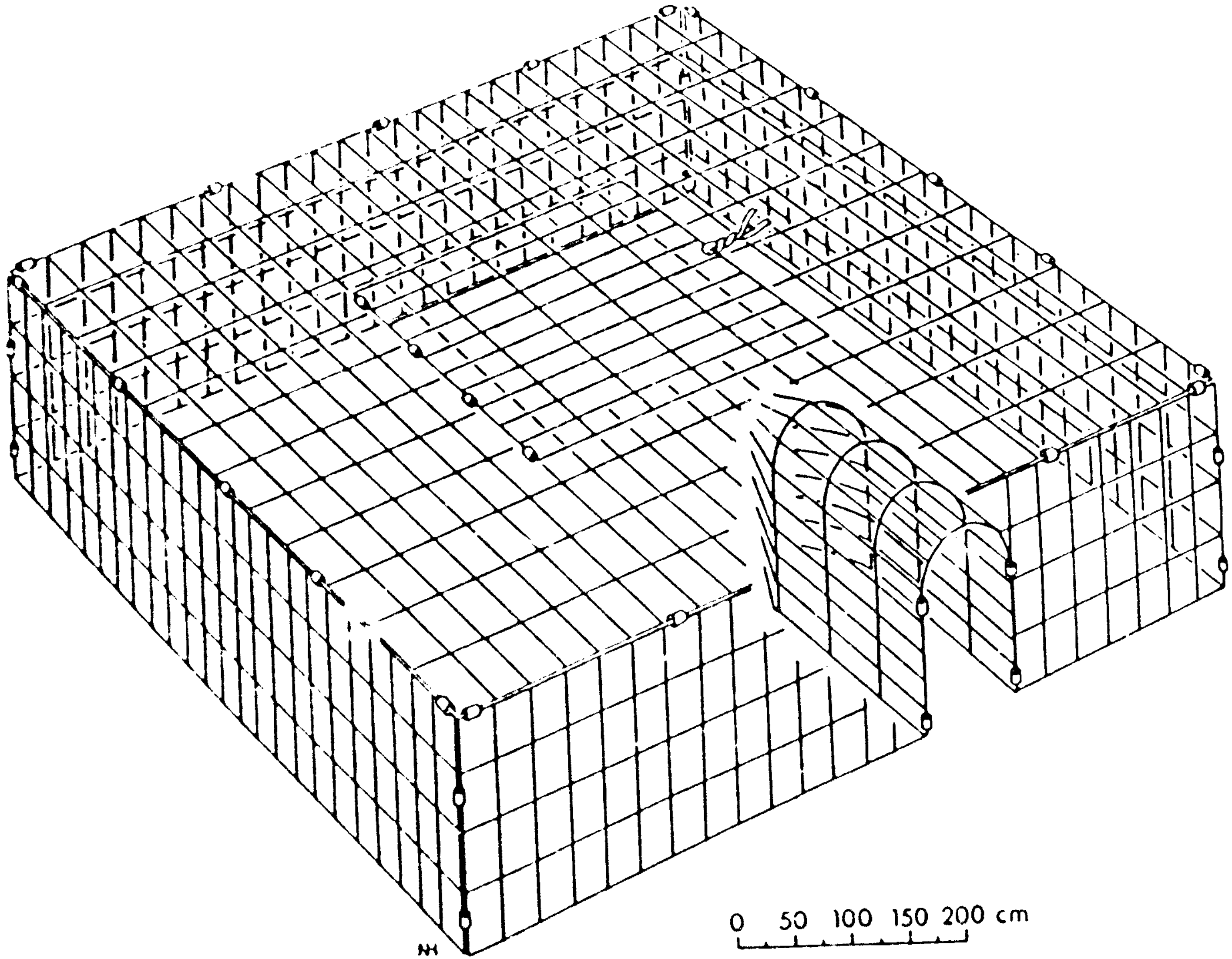

Figure 4. (Cont'd) (C-design effective for ground feeding birds, especially blackbirds, starlings, and mourning doves.)

House sparrows do not possess alarm/distress calls and usually only respond weakly to the alarm/distress calls of other species. House sparrows rapidly adjust to manmade noises; therefore, the various acoustical disturbances used against birds are usually not very effective (Clark 1976, Fitzwater 1983).

The wetting agent, Tergitol, has been used for large scale lethal control of house sparrows.

The most widely used method to eliminate sparrows from a given area is live-trapping with baited traps (Fitzwater 1983). By this method, nontarget species can be released unharmed. However, sparrows once caught will not be retrapped. Fitzwater (1983) illustrates the design of 12 traps which have been effective for catching sparrows. The traps fall into three generic categories.

1. Funnel traps (Figure 4) are the simplest and most commonly used but must be checked frequently since escape is easy. The working principle is identical to that of the well known minnow trap. Since the openings are tapered inward, it is much easier to enter the trap than to exit. The Australian crow trap (Figure 3) is a common example. Modifications to this design (or to any funnel trap) consist of varying the opening size to accommodate different sized species. Live decoy individuals securely penned in a separate compartment inside, make these traps more effective. Of course, decoys must first be caught.

2. Automatic traps (Figure 5) possess a higher catch rate since there is no escape. Birds enter a baited or false nest-box compartment which is counterbalanced. The weight of the bird drops it into a holding compartment and the "nest box" springs back into place awaiting another victim.

3. Triggered traps (Figure 6) catch single birds or a small feeding flock, depending on trap design. The nest box trap is a common design used often on starlings. The bird triggers a closing door when it enters the "decoy" bird house. In some triggered trap designs a watcher must spring the net or trap at the appropriate moment. Most species of sparrows can be caught in these trap designs.

Gulls

The simplest way to discourage gulls is the effective management of garbage or refuse, especially open dumps. Since gulls are the bird species that represent the greatest hazard to aircraft, garbage dumps are eliminated from the vicinity of airports. Gulls have been controlled at airports by breaking their eggs and spraying the nests with a water-oil-formaldehyde mixture (Seubert 1966). Starlicide toxic baits have been used to control gulls nesting in seabird colonies. The avian alarm repellent Avitrol has been used to move gulls from airports, fish hatcheries, and landfills (Jim Forbes, personal communication).

A very effective method of excluding gulls from an area is the use of an overhead canopy of nylon monofilament line or stainless steel wire (see *Monofilament Line*, p 59). Gulls are susceptible to recorded alarm/distress calls (Frings et al. 1955). They have also responded to gull corpse models. Cannon or rocket nets, although labor intensive, can be used to capture gulls when other methods are impractical. (See **Trapping**, p 59).

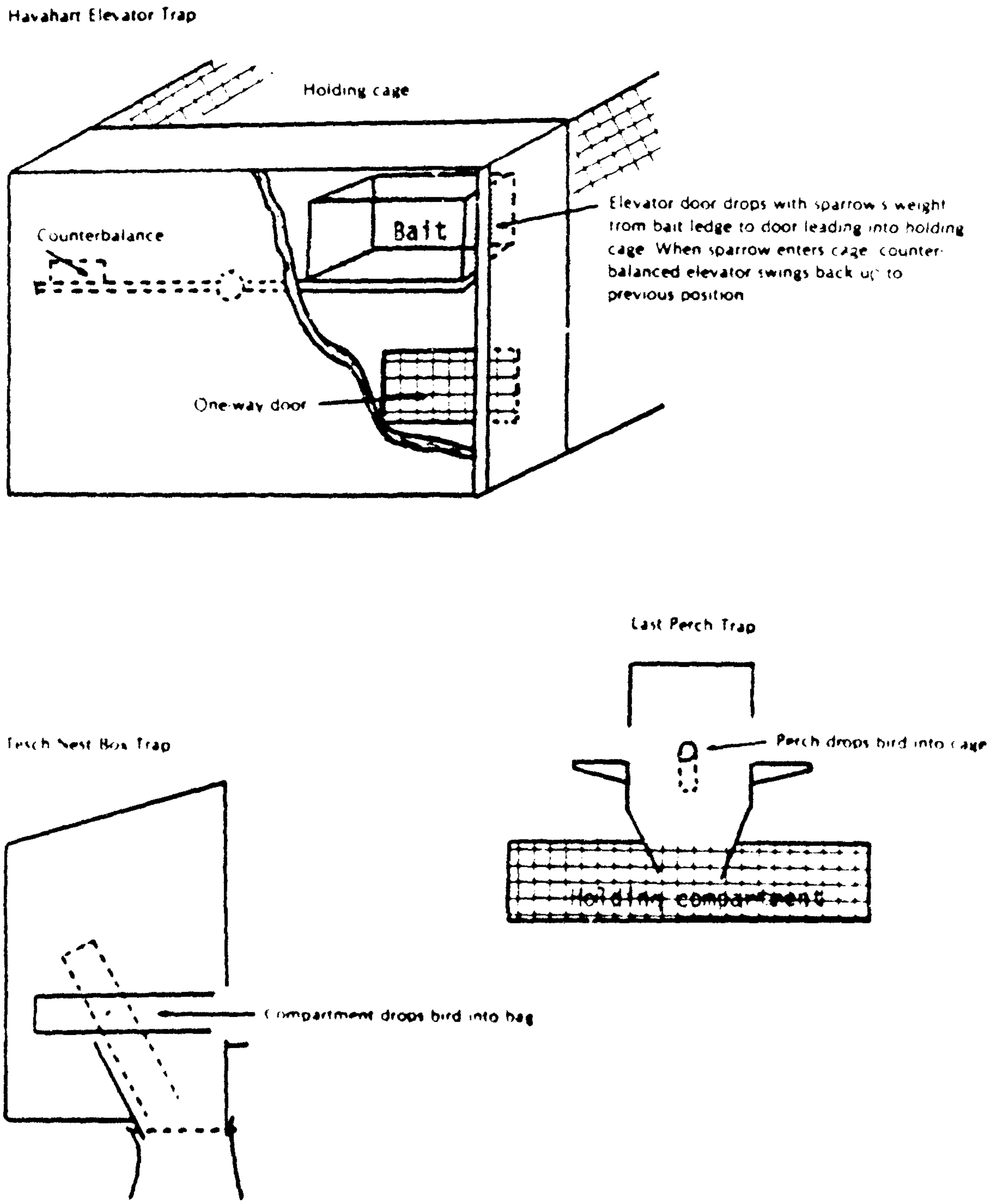

Figure 5. Automatic traps commonly used for sparrows. (Fitzwater 1983).

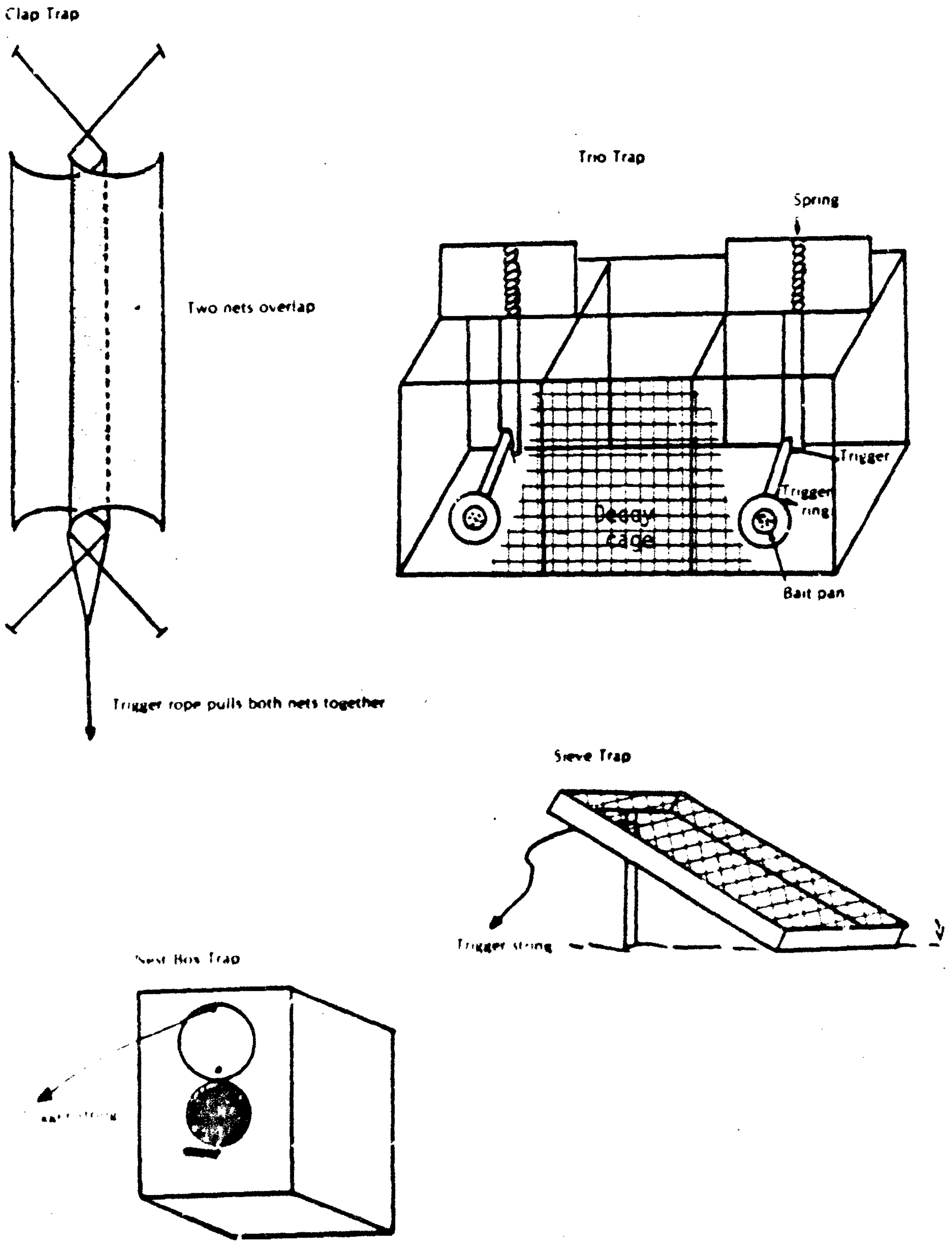

Figure 6. Triggered traps. (Fitzwater 1987).

Canada Geese

Canada geese are attracted to lawns for two important reasons. The grass supplies an appropriate food source, and the open character and short grass provide grazing opportunities while they monitor approaching predators. They will not graze in tall grass or in dense weedy or shrubby growth. Therefore, habitat modification would be an obvious method to eliminate geese. However, this is not usually acceptable (e.g., golf courses, beaches, recreational areas). Alternative grazing sites could be provided so that they may abandon an area where they are a nuisance. This could be reinforced if they were harassed or frightened in the nuisance area and the alternative area is baited with high preference food items (e.g., corn).

A variety of methods have been tried to cope with goose problems (Mott 1988a). Exclusion with perimeter fences, electric fences, or overhead wire have only had limited success. Visual frightening devices such as scarecrows, flags, or metallic reflective tape have only been effective when combined with acoustic devices such as propane cannons, shooting and pyrotechnics. Mott and Trimbrook (1987) and Penrod (1988) found that a combination of both alarm/distress calls and pyrotechnics were effective at repelling Canada geese from campgrounds at U.S. Army Corps of Engineers reservoirs in Tennessee.

Cannon or rocket nets have been used to capture geese when other methods were impractical. During the summer molting period, Canada geese cannot fly, making them easier to capture and transport to a more desirable location. This method has been used as a management tool (Ed Cleary and Ed Penrod, personal communication). (See Trapping, p 59). A recent report summarizes control methods for protecting grain crops from waterfowl (Knittle and Porter 1988).

Methiocarb has been used successfully as a repellent on golf courses and lawns. Dimethyl anthranilate is an inexpensive nontoxic food additive (grape flavoring) readily accepted by mammals and approved for human consumption but offensive to birds, including Canada geese. Experiments are presently being conducted by the Bird Damage Control Section of the Denver Wildlife Research Center, U.S. Department of Agriculture, to further assess its effectiveness in repelling Canada geese. Further research is needed on deterring or repelling Canada goose flocks.

Swallows

Swallows are a migratory species and therefore protected by Federal law. A permit from the Animal Damage Control Section of the U.S. Department of Agriculture is necessary before swallow control is implemented. When feasible, exclusion by netting or screening is the most effective method to prevent swallows from nesting, and it requires no permit. Mesh size should be 1.3 to 1.9 cm, but 2.5 cm has also been used successfully (Salmon and Gorenzel 1983). Since plastic netting is susceptible to weathering, especially ultra violet light, the netting could be made removable, and only needs to be in place during the spring nesting season. Swallows generally have a consistent nesting period that varies geographically, depending on the availability of flying insects.

A common control method is the removal of nests with a high pressure water hose (Salmon and Gorenzel 1983). Although this method is effective, swallows are persistent at rebuilding nests, and it may take many treatments before swallows abandon the locality to look for alternative nesting sites. Usually the swallows will return the following year.

Toxins, trapping, or shooting are not permitted for swallows. Repellents and frightening devices have not been effective (Salmon and Gorenzel 1983). Al Bivings (personal communication) has had success in dispersing purple martins from shopping malls and aircraft hangars using propane exploders. Bivings (1988) recommends the use of plastic netting as the most important method of controlling objectional roosts of purple martins.

Swallows have been known to build nests on sticky repellents and porcupine wire. Additionally, these devices facilitate nest adhesion. All the factors involved in swallow nest placement are not yet totally understood by biologists, but architectural design and surface texture play important roles. Smooth surfaces and metal surfaces are generally avoided as nest substrates, unless they are located at a joint or junction where the birds can get a foothold.

Woodpeckers

Exclusion with hardware cloth, plastic netting, burlap, and metal sheathing has been successfully used to prevent reccurring damage to trees or houses that were selected as favorite drilling spots by woodpeckers.

Loud noises (e.g., gas exploders and banging on a garbage can) have successfully relocated woodpeckers if the harassment is repeated every time the birds return (Marsh 1983). Ribbons, pie pans, or aluminum foil strips (1 m long by 5 cm wide) can be tied so they move with the wind, and placed where woodpeckers are causing damage, to frighten the birds off (Hawthorne 1980).

Pentachlorophenol has been used to discourage woodpeckers from enlarging holes (Fitzwater et al. 1972). However, Marsh (1983) reports that neither pentachlorophenol nor creosote treated utility poles and fence posts are protected from woodpeckers. A 5 to 10 percent paste of quinone was effective in repelling woodpeckers, but the compound is no longer available (Schafer 1979).

Sticky repellents (e.g., Tanglefoot, Roost No More) are recommended by Ostry and Nicholls (1976) to discourage sapsucker drilling, and by Marsh (1983) to discourage woodpeckers. Individual woodpeckers have been controlled by shooting, or rat-traps baited with suet or nut-meats, under a permit from the U.S. Fish and Wildlife Service (Clark 1976).

Crows, Ravens, Magpies, and Jays

Ravens are often scavengers. Landfill and garbage management practices and using trash containers with snug fitting lids are effective at deterring ravens.

Ravens have been effectively controlled under field conditions by Starlicide treated meat (Larsen and Dietrich 1970), and Starlicide treated hard-boiled eggs (Paullin 1987). Because of the relative intelligence of ravens, shooting or cannon-net trapping has not been effective. During the summer of 1989 a raven reduction program is planned in the western and eastern portions of the Mojave Desert in an attempt to reduce raven predation on declining desert tortoise populations (U.S. Department of the Interior 1989). Hard-boiled eggs, each treated with 1 milliliter of a 10 percent solution of Starlicide concentrate (98 percent) will be placed in artificial nests on elevated

platforms. At this Starlicide concentration each egg contains the lethal dose for eight ravens. The baiting program will be conducted at landfills and the prebaiting period will be used to assess potential hazards to nontarget species.

Acoustical frightening devices: gas exploders, shell crackers, recorded alarm/distress calls, and electronically generated noises have been used effectively to disperse crows and magpies from nut orchards. Crows respond well to alarm/distress calls. However, acoustics have not usually been effective against jays (Besser 1985). Scarecrows are not generall' effective against crows (Conover 1985a).

Whole corn baits treated with the frightening agent Avitrol have successfully protected pecan trees from crows (Wilson 1974). Methiocarb has been inconsistent in protecting nut crops from corvid species (Hall 1984). Two seed-treatment repellents are federally registered for preventing crow damage to sprouting corn seedlings: refined coal tar with creosote (Stanley's Crow Repellent®) and copper oxalate (Crow-Chex®) (Johnson and Altman 1983).

Starlicide treated whole corn baits have been used to kill crows, and treated pistachios used to kill scrub jays that were damaging California nut crops (Besser 1985). These were experimental studies since Starlicide is not registered against any corvid species.

Crows have been successfully captured uninjured using the common Australian Crow Trap (Figure 3, a large decoy trap) or size 0 or 1 steel traps whose jaws have been wrapped with rubber or cloth (Kalmbach 1937b).

Shooting is a common control method for crows, ravens, magpies, and jays. A federal permit is necessary to shoot jays, but a permit is not necessary for crows, ravens, and magpies if they are depredating or about to damage agricultural products.

Ecgles, Hawks, and Owls

Raptors are all protected by Federal law so an appropriate permit is necessary for their control. Toxins are illegal. Even visual or acoustical repellent techniques may need a depredation permit from the U.S. Department of Agriculture. Since raptors are highly beneficial to the environment, aesthetically appealing, and many species are becoming rare or even threatened/endangered, raptor control should never be considered.

From the historical perspective, baited or unbaited pole traps, like the Verbail (Figure 7), bal-chatri trap (Figure 8), Swedish goshawk trap (Figure 9), shotgun nets, snares, and shooting have all been used to capture or kill raptors. Pole traps have been very effective, especially in open country, since raptors actively seek out observation posts. Bal-chatri or similarly constructed traps have also been very effective. They require live prey in the trap. When the raptor attacks the decoy, its talons become entangled in the loops of nylon monofilament line. Struggling aids to tighten the nooses. Canron or rocket nets are the accepted method and have been used to successfully capture raptors uninjured (Bloom 1987, Grubb 1988).

The relative effectiveness of frightening devices or repellents for raptors has not been adequately researched.

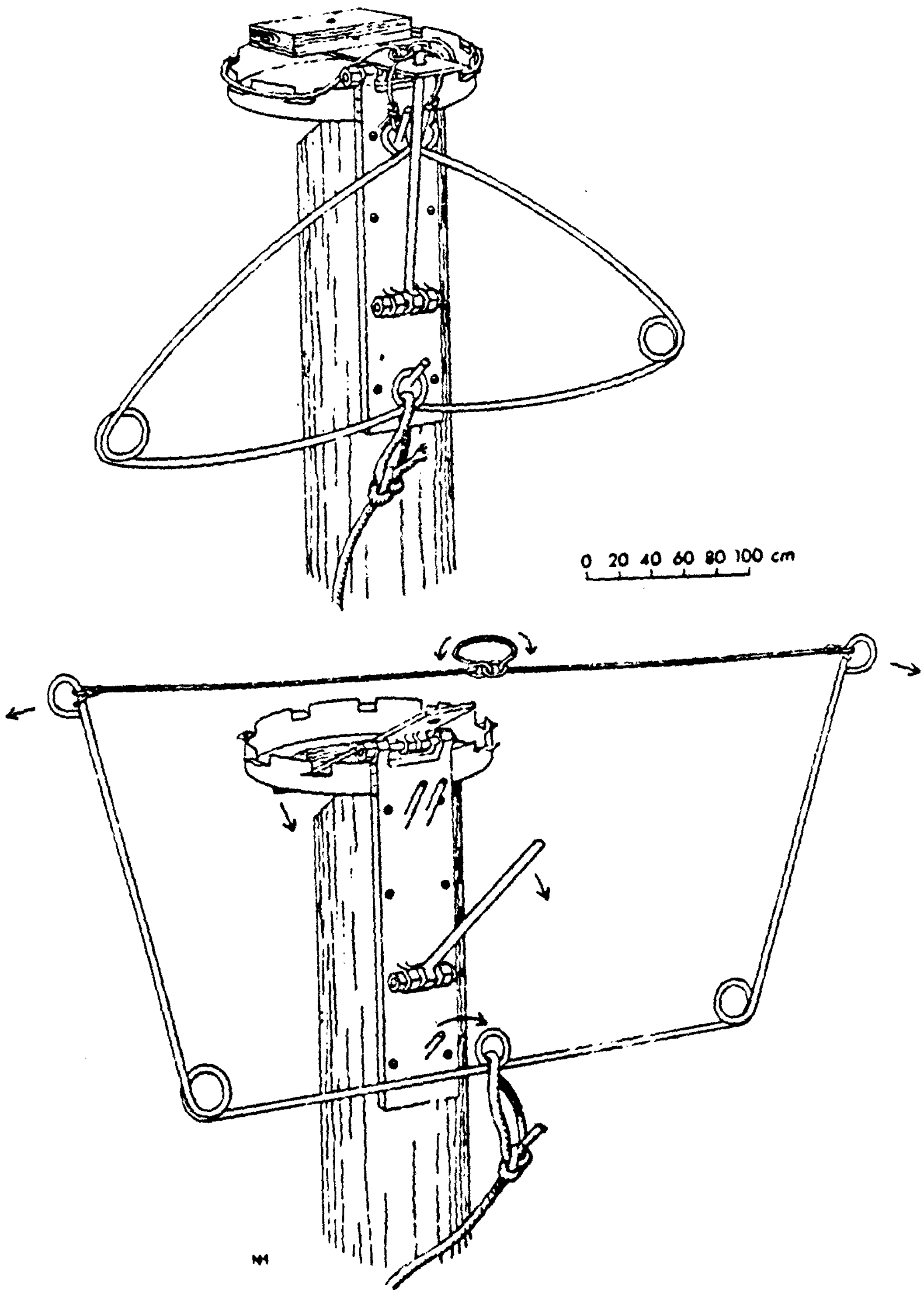

Figure 7. Verbail trap for raptors (landing on the treadle releases the spring arms which throw the noose around the bird's legs). (Lefebvre and Mott 1983).

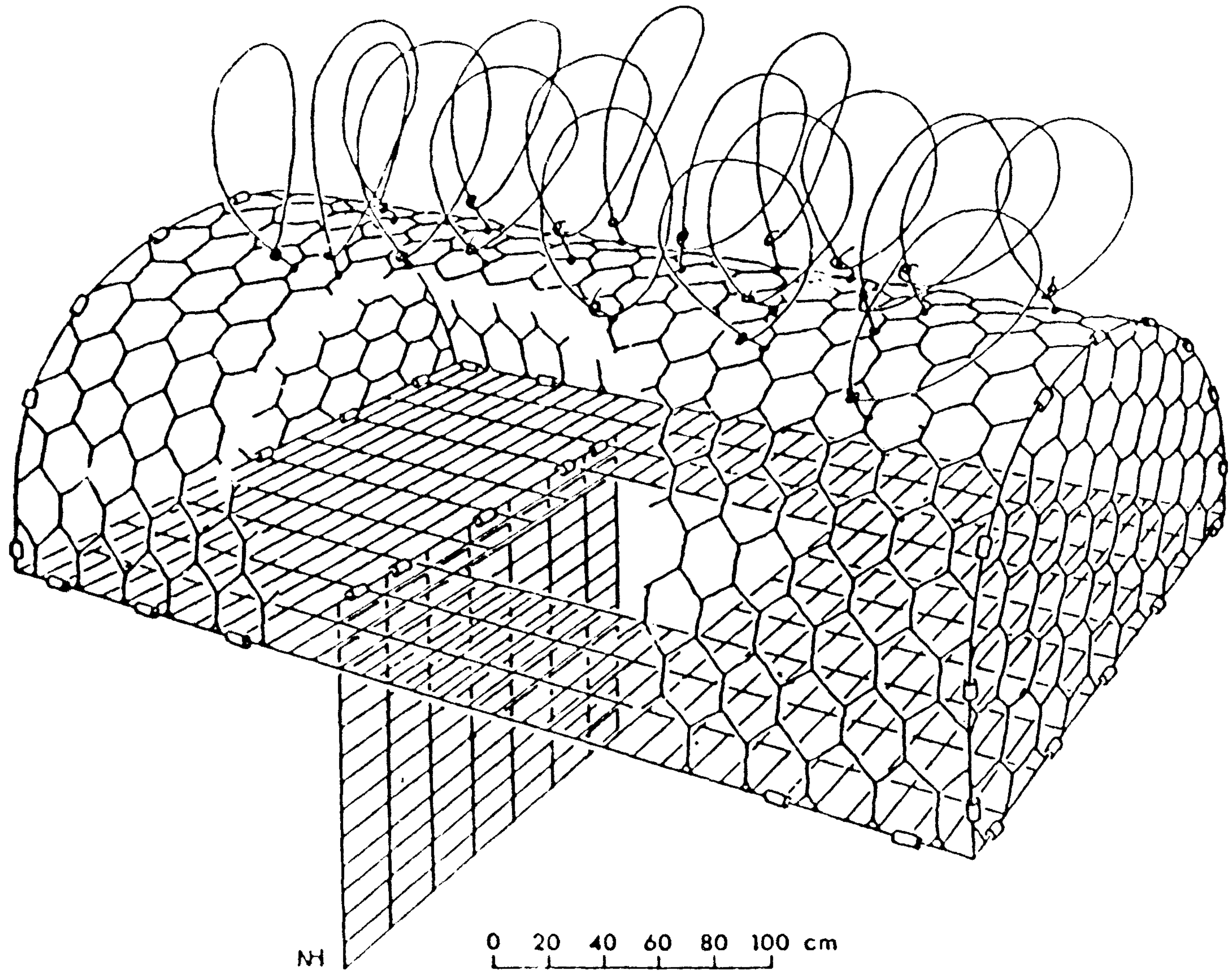

Figure 8. Bal-chatri trap for raptors. (Lefebvre and Mott 1983).

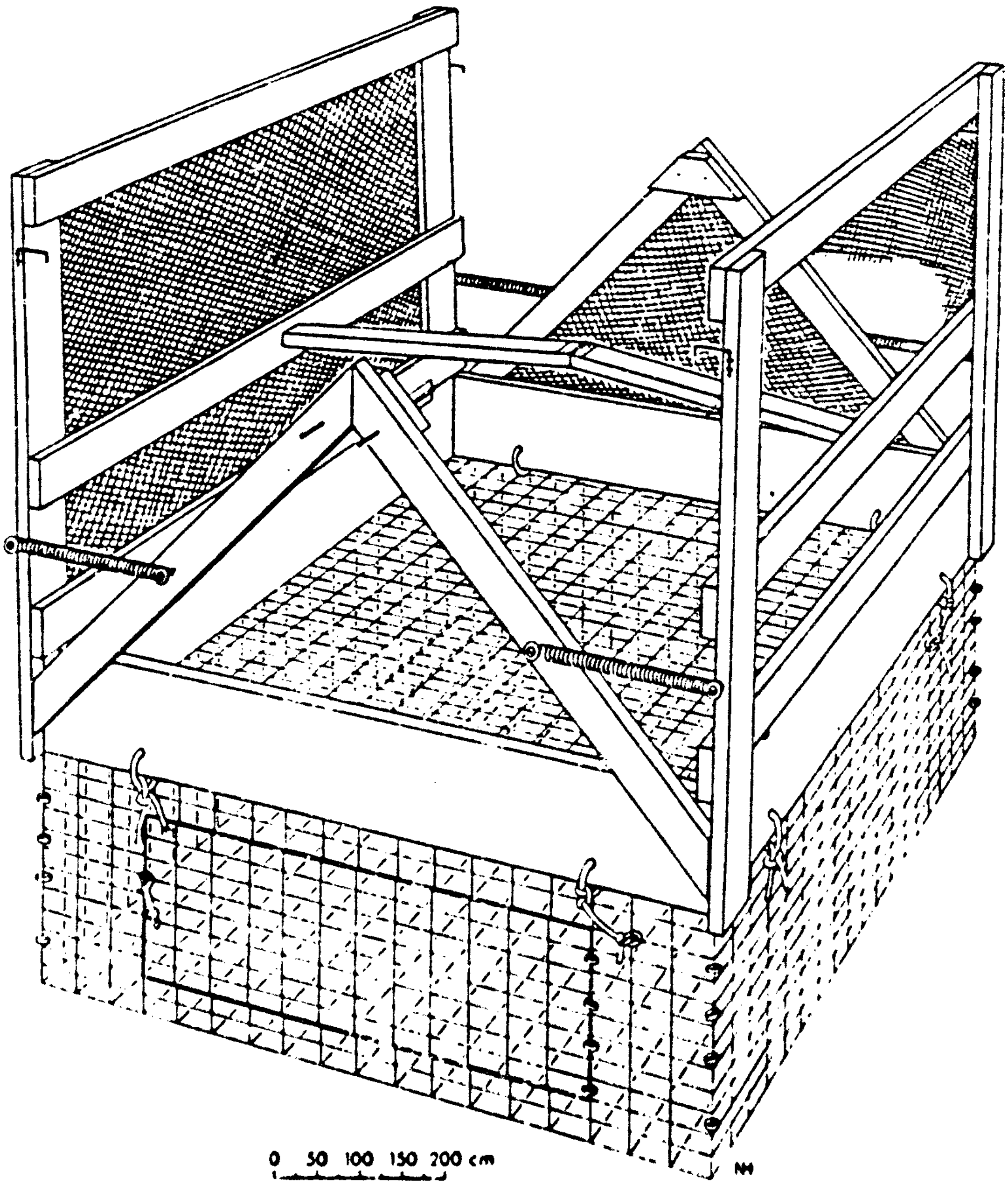

Figure 9. Swedish goshawk trap (Lefebvre and Mott 1983).

Bird Roosts

Habitats would not be suitable for roosts if they were heavily pruned (canopy opened) or if the tree density was reduced to less than 720 trees/ha (at least for fall roosts). However, heavy pruning every few years or thinning the trees may be economically unsound. At several r... ted roosts, 80 percent of the trees would have to be removed to achieve a density of 720 trees/ha (Lyon and Caccamise 1981, personal observation). However, once a roost relocates it may never come back to its original site, so a single treatment may be sufficient. Also, it is important to consider that habitat changes force the birds to relocate to another locality, which may be even more inconvenient for man. Eighty percent of the roosts in Tennessee are located in urban-suburban sites (Mott 1984).

Frightening birds out of roosts, including the use of chemical repellents and helium-filled balloons has dispersed roosts, with 47 to 100 percent population reductions reported using balloons (Mott 1980, 1985). However, relocations will not solve the problem in a community with a persistent roost problem. Balloons cannot be used in large roosts where there is a high tree density or in windy weather (> 19 km/hr [10 mph] winds) (Don Mott, personal communication).

Sometimes the use of recorded alarm/distress calls (Brough 1969), exploders, firecrackers, shellcrackers, or other acoustical devices can be effective at moving or dispersing a roosting flock, even a large one. These devices may solve a local roosting problem temporarily, but the flocks may return or relocate in a nearby area.

Wetting agents (e.g., Tergitol) have been used for large-scale lethal control of winter blackbird-starling roosts, under the supervision of the U.S. Department of Agriculture, Animal Damage Control. The method is effective but requires rather exacting weather conditions. However, recent developments in water delivery systems have greatly extended the utility of this method (Stickley et al. 1986, Mott 1988b). Large-scale lethal control has not been favorable with the public (Free 1975, U.S. Army 1975, Graham 1978).

Starlicide has been used at blackbird-starling roost sites to attempt population control at the source (Knittle et al. 1980), but further research is necessary to evaluate potential environmental and nontarget species hazards (Mott 1984).

Histoplasmosis, caused by spores of the fungus *Histoplasma capsulatum*, is the major human health hazard associated with large persistent winter blackbird-starling roosts. Researchers or workers around suspected histo-sites should be restricted to those personnel whose skin tests register histo-positive, since these individuals already have acquired some immunity to histoplasmosis. However, these individuals may still be susceptible to a large dose of *H. capsulatum* spores. Immunization vaccines against histoplasmosis have not been developed, mainly because most infections are benign, and the fungus has a world-wide distribution (Weeks and Stickley 1984). However, high risk occupations would benefit from a vaccine: Laboratory and construction workers, public health epidemiologists, wildlife biologists, and speleologists (Weeks and Stickley 1984).

Burying *Histoplasma*-infected sites with more soil or using soil fumigants and other chemicals has not been successful in discouraging fungal growth (Tosh et al. 1966b). Creosol compounds and pentachlorophenol in fuel oil are effective but environmentally unacceptable (Weeks and Stickley 1984).

Formalin solutions are a practical and effective means to decontaminate soil containing *H. capsulatum* (Tosh et al. 1966b, Weeks 1984b). The formalin solution is prepared by diluting commercial grade formaldehyde with water to form a 5 percent solution (0.15 percent by weight of formaldehyde gas). The formalin solution is applied at a rate of 13.5 L/m^2 in three applications, each on separate days (Weeks 1984b). When bird manure is deep, a dose of 40.7 L/m^2 should be applied on alternate days to insure deep soil penetration (U.S. Army 1985). The formalin solution should saturate the soil to a depth of 20 cm. Vertical walls should be decontaminated at the rate of 270 ml/m^2 while horizontal surfaces need 6.8 L/m^2 (U.S. Army 1985). Contaminated equipment should be soaked in 5 percent formalin for 15 minutes. Formalin also eliminates beneficial fungi, bacteria, and all the microorganisms from the soil. Although formalin rapidly biodegrades in the environment, treated soil may possibly be sterile and unproductive for extensive periods. Formaldehyde can cause severe irritation to the mucous membrane of the respiratory tract and eyes. Repeated exposure may cause dermatitis or allergic reaction. At present, there is a strong controversy concerning the carcinogenicity of formaldehyde, and a variety of tests have shown it to be mutagenic.

Agriculture

Grain Crops

Blackbirds, especially the red-winged blackbird and the common grackle, can cause local damage to grain crops--primarily corn, rice, sunflower, and sorghum. Crop depredations have been more severe near roosting sites. Probably the most effective and economical method to disperse blackbird flocks depredating grain crops has been the use of gas exploders. The pyrotechnic devices available are equally effective but require more manpower and pose a greater fire hazard.

Experiments with hawk-kite models mounted to helium balloons have been successful, and although cost-effective, are overall more expensive than gas exploders. Kite models are vulnerable to weather and vandalism, but avoid the problems of noise pollution and fire hazards. A mechanical scarecrow has recently been developed, but its effectiveness is not yet known. Further research is needed with predator models.

A recent development has been the use of reflecting tape stretched over agriculture crops in rows spaced at 3 to 10 m. (See *Reflecting Tape*, p 69). The tape gives both visual and acoustical cues to frighten birds. The tape is presently being evaluated in many countries worldwide, to protect a wide variety of crops. Preliminary findings show that the tape has been effective at reducing bird damage from many avian grain pests.

Avitrol, a compound that elicits alarm calls in birds, and methiocarb, which produces a taste aversion in birds, have been used to protect sprouting and ripening grain crops. Their effectiveness has been highly variable, particularly with Avitrol. The timing of applications is essential with Avitrol. These chemicals are not often cost-effective, since potential damage to the crop must be relatively high if the cost of the compound is to be recovered.

Recorded alarm/distress calls and various electronic noise makers have been only partially successful. Further research is needed to optimize the use of acoustics to repel birds.

In small garden plots of sweet corn, Conover (1987) was able to reduce bird damage by 90 percent by placing platic bags around the ears of corn. Dolbeer et al. (1986b) have suggested the development of corn hybrids that are more resistant to blackbird depredations. Recent investigations have suggested that varietal resistance may represent a viable approach for the control of bird depredations to sunflower crops (Mason et al. 1989).

The time of seeding may have an effect on the extent of blackbird depredation on sprouting crops. Bollinger and Caslick (1985) evaluated the relative importance of 12 variables in explaining the variation in blackbird damage among cornfields located near a large roost in New York. Date of silking was the most important predicter of bird damage to corn; earlier maturing fields received greater damage. Delaying rice seeding until mid-April in Louisiana has reduced blackbird damage to the sprouting crop (Wilson et al. 1989).

Flower and Vegetable Seed Crops

House finches and goldfinches (American and lesser) are known to feed heavily on mature flower and vegetable seed crops. The most effective method of protecting these crops is through protective plastic netting. Although expensive, it is cost-effective because of the very high value of the crop, and the potential serious damage to unprotected crops. House finches have also been controlled by toxic bait using rape seed and/or canary grass seed or by trapping. Toxic baits should never be used for these species.

Horned larks and white-crowned and golden-crowned sparrows can feed extensively on newly planted seeds or sprouts/seedlings of flower and vegetable crops. Horned larks are controlled by toxic baits dispersed at ground level in troughs dug in the soil, since this species is accustomed to following furrows or seeder tracks (Clark 1976). White-crowned and golden-crowned sparrows generally feed near shrubby or brushy areas, so the elimination of this habitat component is important in protecting newly seeded or sprouting agricultural fields. Toxic baits have been used in the past, and trapping has been very effective using lily-pad, clover-leaf, or modified Australian Crow traps (Clark 1976). Toxic baits should never be used for these species.

Fruit Crops

Fruit is highly preferred by many species of birds. These species include bird pests such as the starling and grackle; common birds such as robins, finches, cardinals, catbirds, and blue jays; and also desirable species such as bluebirds, waxwings, thrushes, thrashers, orioles, and mockingbirds.

Plastic netting is the most effective method for protecting fruit crops. Although expensive ($750 to $1,300 per ha) and labor-intensive, it is usually cost-effective when protecting valuable crops such as strawberries, blueberries, and grapes. The first experimental study to evaluate the effectiveness of reflecting tape to protect blueberries demonstrated that the tape was ineffective against avian frugivores.

Methiocarb, an avian taste aversion compound, has generally been successful in protecting a wide variety of fruit from all frugivorous bird species. Exploders and pyrotechnics have been effective in dispersing birds out of orchards. Hawk-kite models suspended from helium balloons have been used to protect blueberries. Although predator models were the least expensive technique, plastic netting and methiocarb were more effective at protecting fruit crops.

Decoy traps have been effective in eliminating local birds depredating orchards. An advantage of live-traps is that desirable or protected species can be relocated and released unharmed. In 17 months of trapping, 13,000 house finches were trapped in 4 large decoy traps, and 9,000 cedar waxwings were caught using a single decoy trap for 1 week (Besser 1985).

Feedlots

The primary bird pest at livestock and poultry feedlots is the starling. During severe winter weather, especially after a heavy snowfall, grackles and, to a lesser extent, red-winged blackbirds may cause severe local problems. Feedlots located near large winter blackbird/starling roosts are particularly vulnerable. The primary means of control for all bird species at feedlots is the toxin Starlicide. In a recent survey of Kansas feedlots, Lee (1988) found toxic baits were used four times as often as shooting to control depredating birds. Frightening devices were used almost as much as shooting. Toxic perches were also used. Research is planned to evaluate live Harris' hawks (*Parabuteo unicinctus*) to scare off birds, wire perches to electrocute birds, and dimethyl anthranilate as a food repellent. Feed management to limit the availability of feed to birds has been suggested, but may be too inconvenient and labor intensive. Livestock ration is being produced in pellet sizes too large to be acceptable to birds, but chicken feed cannot be made larger.

7 SUMMARY

This technical report has:

1. Provided a perspective analysis of birds in society and science.

2. Provided a descriptive survey of bird problems.

3. Provided a survey of birds as potential disease vectors.

4. Identified and discussed state-of-the-art methodologies in bird management and control.

5. Provided extensive and diverse references: for background information, as a bibliography for problem solving, and as a foundation for initiating specific research objectives.

Bird problems are extremely diverse in nature and magnitude. Persistent geographical and seasonal patterns are evident. Problems and effective solutions may be highly site specific. There are no simple, general, optimal, or "best" solutions for managing or controlling bird populations. Even when the problem is well defined, there is no guarantee of success. There have been as many failures as successes, despite the intensive efforts of academic and private institutions, Federal, State and local agencies, as well as local individual efforts. However, an assessment of the literature suggests that the experience gained over the past several decades enables the informed avian pest manager to achieve at least a moderate degree of success, if not complete success. The prerequisite of any bird management/control effort is to obtain as much information as possible about the nature and magnitude of the problem(s), including pertinent site-specific details.

Bird control is a very sensitive public and political issue, since people possess a strong appreciation and affection for birds. Birds are abundant, possess unusually diverse ecological roles (niches), and are found in virtually all habitats. They are visually and vocally the most obvious component of the wildlife fauna in wilderness, as well as rural and urban environments. Nonconsumptive wildlife recreation (observing, photographing, and/or feeding wildlife, as well as hiking, camping, and canoeing) is engaged in by a larger segment of the population than fishing and hunting combined, in both the United States and Canada. This represents a major economic investment in equipment, clothes, field guides, travel, and lodging; bird seed, feeders, and houses. Birds represent the single most important component of this recreation. Economically, birds also represent important consumers of insect pests. Even nuisance species are important consumers of deleterious insects (red-winged blackbirds, starlings, and grackles are noteworthy examples), and weed seed (cowbirds, red-winged blackbirds).

There has recently been strong interest and research on wildlife in urban/suburban settings, as well as the management of nongame species, not only as a natural resource in themselves, but as valuable indicators of timber, range, and watershed management practices. Again, birds form the most important component of these programs and research emphasis.

Scientifically, birds have been among the most intensely studied organisms and represent the best researched group of animals by nonprofessional biologists. Birds have been exemplary in the development of ecological, island biogeographic, and ethological theories.

The social, scientific, and economic importance of birds and their public attention and popularity must be thoroughly understood, considered, and realistically appraised whenever a bird management/control program is planned, developed, and implemented.

Bird problems are related to one or more of the following categories: (1) damages and economic losses, (2) human health and safety, (3) aesthetics, (4) inconveniences, or (5) competition with native species and brood parasitism. Six bird species are responsible for the majority of problems in the United States. Three species were introduced from Europe (common pigeon, house or English sparrow, European starling). Three native species: red-winged blackbird, common grackle, and brown-headed cowbird have dramatically increased their populations and distributions in modern times. This increase is most likely attributable to deforestation/forest fragmentation, the increase in ecotones (edges), the large-scale increases in grain crops, and the proliferation of cattle, swine, and poultry feedlots. These birds find an almost infinite supply of grain in agriculture fields (including those already harvested) and livestock/poultry feeding pens. These feeding areas, especially livestock pens, are particularly necessary during severe winter weather. The availability of adequate and predictable winter food resources may have been the limiting factor on populations of these species in the past.

The major bird problems and research efforts for their solution have been primarily in three areas: (1) winter blackbird--starling roosts, (2) agricultural and feedlot depredations, and (3) safety hazards to aircraft. Most local nonagricultural problems are caused by pigeons, starlings, house sparrows, gulls, Canada geese, or woodpeckers. Research directed at managing local problems has not been extensive. This is mainly because the problems are so site specific and variable that overall or comprehensive management/control plans cannot easily be realized or developed. Additionally, the local problems are not as visible, publicized, or economically important as the three areas cited above. Local problems are generally solved by the large number of small professional pest management operators, who acquire a great deal of on-the-job experience and expertise. Generally, their results are not published in the scientific literature. However, practical bird control experts present papers at conferences specializing in pest management (e.g., The Bowling Green University series of Bird Control Seminars, The Vertebrate Pest Conferences, Wildlife Damage Control Conferences, etc.). These proceedings represent excellent sources of practical nuisance bird control methodologies/strategies, and have liberally been used and referenced in the preparation of this report. Additionally, the lessons learned at controlling roosting, agricultural, and airport bird problems have potential implications for managing bird problems at U.S. Army installations, including Corps of Engineers Civil Works Projects.

Several bird problems, including roosting flocks, can be completely avoided by appropriate considerations in building design and in landscaping. Roosting birds generally select dense closed canopy saplings or conifer groves or plantings. Roof edge trimming or decorations, eaves, ledges, etc., are potential nest sites, particularly for pigeons. Horizontal air vents, breathers, inlets, etc. invite nesting starlings. Any kind of cracks or crevices attract starlings or house sparrow nests.

Exclusion of birds by devices such as hardware cloth, netting, plastic screening, and aluminum flashing is the most effective, safest, and most permanent way to prevent loafing, perching, nesting, or foraging birds from reaching their destination. Care must

be exercised to use strong material, sufficiently small mesh size, and the material must be completely and securely fastened. Birds are strong, persistent, ingenious, and can fit through surprisingly small openings relative to their body sizes. Plastics and fibers, especially nylon, suffer weather deterioration, and UV-stabilized grades must be used. The recently available UV-stabilized black polypropylene netting/screening comes in a variety of mesh and strand sizes, is easy to handle and relatively strong. Exclusion techniques are usually expensive and labor intensive, but may be cost effective in the long run.

Gulls and herons may be effectively excluded from an area by overhead nylon monofilament fishing line or stainless steel wire. Monofilament is inexpensive and much easier to install (stainless steel wire kinks easily), but it is weaker and deteriorates rapidly on exposure to UV radiation.

Methiocarb is a very effective avian taste repellant that has been used primarely to protect fruit crops, but it has been applied to grain products, and to protect lawns from Canada geese. Dimethyl anthranilate (grape flavoring) and related compounds are nontoxic and approved for human consumption. Experimental trials have shown them to be effective taste repellants for a variety of bird species. Research is continuing on these components by the Bird Damage Control Section of the Denver Wildlife Research Center, U.S. Department of Agriculture.

The use of toxic baits to remove undesirable birds is highly effective, when done correctly. Cyanide salts should never be used because of extreme toxicity and the potential of affecting nontarget species, including humans. Strychnine and Avitrol have been used for all the usual pest bird species, and are very effective. Toxic baits should only be used by licensed experienced professionals, preferably personnel from Federal or State agencies responsible for Animal Damage Control. A highly desirable feature of Avitrol is that its toxicity can easily and consistently be controlled by varying the proportion of the active ingredient (4-Aminopyridine) incorporated with the grains, seeds, or fruit used as bait. Care should be taken to select bait that is highly acceptable to the target species, but minimally impacts nontarget species. For example, the use of whole kernal corn is acceptable to pigeons, but will not be ingested by small songbirds (nontarget species). Avitrol can be used in high concentrations to kill birds directly at the bait site. More desirably, Avitrol can be employed as a slow toxicant, allowing the birds to disperse from the bait site, minimizing the evidence of a bird kill and negative publicity. However, the dispersal of carcasses increases the potential for secondary toxicity to predators and scavengers.

Starlicide is a slow acting toxicant that even in low concentrations is very toxic to starlings, blackbirds, crows, and ravens. Starlings completely metabolize the compound in 2.5 hours, and minimal survival time after ingestion, even at very high doses, is 3 hours. Therefore, there cannot be secondary consumption of the toxin by scavengers or predators feeding on carcasses. Starlicide is much less toxic to mammals than to birds. Bird species vary widely in their susceptibility to Starlicide. Turkeys and owls are sensitive, but some hawks and sparrows show a low toxicity to the compound.

When using toxic baits, prebaiting is an essential step in achieving maximum bait acceptance by the majority of target individuals. Prebaiting is the consistent placement of untreated bait in appropriate troughs or trays in the same location and with the same type of bait, for several days to two weeks. The location should be acceptable and convenient for the target species, but as unavailable as possible to nontarget species. The prebaiting period concentrates the birds and gives them confidence in the bait, containers, locality, etc. Additionally, it minimizes the damage to nontarget species. If

the treated bait were introduced immediately, only a few individuals would be affected, since their reaction to the toxin would discourage others from feeding on the bait.

Toxic perches containing solutions of contact poisons are only acceptable and legal for controlling small local problems with house sparrows, starlings, or pigeons. The toxic solution is wicked to the surface of the perch, where it is absorbed through the bird's feet. The perches are strategically placed so that they will be used by the target species. The number of perches used and their exact placement are site- and problem-specific. Fenthion is the usual toxin, and death occurs in about two days. Poisoned birds can disperse widely and become easy targets for predators. Therefore, toxic perches are potentially a serious environmental hazard for secondary toxicity. Round perches are used for eliminating starlings or sparrows, but flat perches are necessary for pigeons. Since the perches are hazardous to all bird species, the Environmental Protection Agency has approved their use for only the following locations: in and around farm buildings, pipe yards, loading docks, bridges, in buildings and roofs. A large number of potential toxins and solvent systems have been rudimentarily evaluated, but a great deal of research remains, especially if species-specific toxin systems are to be developed. Endrin has been used as a contact toxin, but since it is a chlorinated hydrocarbon, it is ecologically unacceptable. Like DDT, it is persistent in the environment, and therefore accumulates geometrically up food chains.

An effective and environmentally safe way to remove or control large numbers of blackbirds and/or starlings (e.g., thousands to millions of birds) is through the use of the surfactant PA-14 (Tergitol) (EPA approved). This compound in a weak aqueous solution removes the waterproof oils on the birds' feathers. When the temperature is low, subsequent wetting of the birds, either by rain or a sprinkler system, produces fatal hypothermia.

Live-trapping and subsequently relocating or killing the birds generally is not cost-effective, but has been reported to be successful with local pigeon, starling, and house sparrow problems. Canada geese, gulls, raptors, and agricultural pests have also been trapped and relocated. The method takes a great deal of time, is labor intensive, and some bird species prove difficult to capture.

Predator models (e.g., hawk-kites suspended from helium filled balloons and animated plastic owls with birds in their talons) have been successful at repelling birds from local areas, but this method requires appropriate maintenance and protection from vandalism. Predator models require problem- and site-specific experimentation in order to achieve optimal success.

Acoustical devices such as gas exploders, pyrotechnics, avian alarm/distress calls, and transmitted noise have been both successful, as well as ineffective in repelling bird populations. Usually, these devices work very well initially, but eventually birds habituate to them, sometimes surprisingly rapidly. All these devices are most effective when spatial and temporal randomness are incorporated. Exploding devices are generally very effective and commonly used to protect agricultural crops. Often a combination of both alarm/distress calls and pyrotechnics or exploders works very well. The main drawbacks of acoustical devices are noise pollution and fire hazards.

Birds possess an unusually large number and variety of external and internal parasites. Additionally, they are subjected to a wide variety of protozoan, bacterial, viral, and fungal infections. Most of these pathogens or parasites can only affect other birds. Sometimes an infection is highly host specific and restricted to a particular species or a certain family or order of birds. Humans and other mammals are not

typically affected with avian parasites or pathogens. However, wild (free-living as well as captive) and domestic bird populations have often infected one another in epidemic proportions. These have included poultry, pigeons, game species, nongame species, and expensive exotics such as pets, aviary populations, and zoo specimens.

Blood-feeding arthropods (insects, ticks, mites, etc.) represent disease vectors that can spread viral, bacterial, fungal, protozoan, nematode, and trematode infections. Despite the large variety and number of these blood-suckers that feed on adult and nestling birds, they are not usually considered serious threats to human health, with one exception. Several strains of encephalitis, an inflamation of central nervous system membranes (caused by a virus), have infected humans, horses, and other mammals, often fatally. Although fatal infections have been reported for many bird species, birds typically act as reservoir hosts, afflicting mammals through mosquito vectors. An effective mosquito management program is the only effective strategy to minimize the health risks of encephalitis.

Chlamydiosis, more commonly known as ornithosis or psittacosis (parrot fever), is a bacterial infection resembling pneumonia in man. Human mortality is low, especially with antibiotic treatment, although the disease is usually fatal in untreated birds. The bacteria can be transmitted in a variety of ways: airborne, bird feces or nasal discharges, a bite by an infected bird, or blood-sucking arthropods. Chlamydiosis is commonly reported in pigeons. The disease is most prevalent among poultry or pigeon breeders and workers, bird-banders, and wildlife specialists closely associated with birds.

Histoplasmosis is a human respiratory inflammation caused by the airborne spores of the fungus *Histoplasma capsulatum*. This species is a widespread soil microorganism, and may become abundant in the vicinity of large blackbird-starling winter roosts, where the roosts have been occupied for three or more years. High nutrient levels combined with appropriate temperature, humidity/moisture, and pH limits, promote rapid fungal growth. The most serious time for airborne infection is when the soil around the roost is dry and subsequent disturbance produces dusty conditions. The spores are viable in abandoned roosts for many years. Although *H. capsulatum* is generally implicated with winter blackbird-starling roosts, any soils persistently enriched with bird or bat droppings over a period of several years (e.g., pigeon, swallow, gull, or goose loafing, feeding, or nesting areas) are potential sites for harboring high spore concentrations of this fungus.

Histoplasmosis is rarely fatal, usually producing cold or allergy-like symptoms. About 90 percent of the people infected with spores (i.e., who register positive antigen serological tests) show no discernible symptoms. Apparently, the severity of infection is directly proportional to the amount of spores inhaled. Histoplasmosis does not appear to affect birds, and birds themselves do not harbor or spread the disease. As a control measure, roosting birds should be discouraged at Army facilities by implementing habitat modification procedures, and dense bird colonies consistently nesting at the same locality should be controlled.

Another fungal infection, cryptococcosis, is commonly associated with pigeon droppings, but infection is possible from the feces of other bird and mammal species. The disease is difficult to diagnose. Advanced serious infections may lead to meningitis, an inflammation of the brain and spinal cord membrane that can be fatal.

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APPENDIX A:

SCIENTIFIC NOMENCLATURE OF BIRDS CITED IN REPORT

Sequence of orders and families follows classification standards by the American Ornithologists' Union. Compiled from Robbins et al. 1983.

Pelecaniformes	
Cormorants	*Phalacrocorax* spp.
Anhinga	*Anhinga anhinga*
Anseriformes	
Swans	*Cygnus* spp.
Canada goose	*Branta canadensis*
Ducks	Six diverse tribes
Peking duck	Domesticated mallard *Anas platyrhynchos*
Falconiformes	
Northern goshawk	*Accipiter gentilis*
Cooper's hawk	*Accipiter cooperi*
Sharp-shinned hawk	*Accipiter striatus*
Golden eagle	*Aquila chrysaetos*
Bald eagle	*Haliaeetus leucocephalus*
Osprey	*Pandion haliaetus*
Prairie falcon	*Falco mexicanus*
Peregrine falcon	*Falco peregrinus*
Merlin	*Falco columbarius*
American kestrel	*Falco sparverius*
Galliformes	
Wild turkey	*Meleagris gallopavo*
Chukar	*Alectoris chukar*
Ring-necked pheasant	*Phasianus colchicus*
Japanese quail	*Coturnix japonica*
Jungle fowl	*Gallus gallus*

Ciconiiformes	
Herons/Egrets/Bitterns	Ardeidae
Great blue heron	*Ardea herodias*
Green heron	*Butorides striatus*
Black-crowned night heron	*Nycticorax nycticorax*
Wood stork	*Mycteria americana*
Ibises	Threskiornithidae
Gruiformes	
Cranes	Gruidae
Rails/Gallinules/Coot	Rallidae
Charadiiformes	
Shorebirds	
Sandpipers/Phalaropes	Scolopacidae
Plovers/Lapwings	Charadriidae
Avocets/Stilts	Recurvirostridae
Two other minor families in	North America
California gull	*Larus californicus*
Ring-billed gull	*Larus delawarensis*
Herring gull	*Larus argentatus*
Great black-backed gull	*Larus marinus*
Laughing gull	*Larus atricilla*
Terns	Sterninae
Columbiformes	
Pigeon or rock dove	*Columba livia*
Mourning dove	*Zenaida macroura*
Psittaciformes	
Monk parakeet	*Myiopsitta monachus*
Strigiformes	
Great horned owl	*Bubo virginianus*

Caprimulgiformes		
Oilbird		*Steatornis caripensis*
Apodiformes		
Hummingbirds		Trochilidae
Coraciiformes		
Belted kingfisher		*Ceryle alcyon*
Piciformes		
Red-headed woodpecker		*Melanerpes erythrocephalus*
Acorn woodpecker		*Melanerpes formicivorus*
Lewis' woodpecker		*Melanerpes lewis*
Sapsuckers		*Sphyrapicus* spp.
Passeriformes		
Alaudidae	Horned lark	*Eremophila alpestris*
Hirundinidae	Barn swallow	*Hirundo rustica*
	Cliff swallow	*Hirundo pyrrhonota*
	Purple martin	*Progne subis*
Corvidae	Blue jay	*Cyanocitta cristata*
	Scrub jay	*Aphelocoma coerulescens*
	Black-billed magpie	*Pica pica*
	Yellow-billed magpie	*Pica nuttalli*
	Common raven*	*Corvus corax*
	American Crow*	*Corvus brachyrhynchos*
Mimidae	Northern mockingbird	*Mimus polyglottos*
	Gray catbird	*Dumetella carolinensis*
	Brown thrasher	*Toxostoma rufum*
Muscicapidae	American robin	*Turdus migratorius*
	Wood thrush	*Hylocichla mustelina*
	Bluebirds	*Sialia* spp.
	Other thrushes	*Catharus* spp.
Bombycillidae	Cedar waxwing*	*Bombycilla cedrorum*

*See the following page for similar species possessing restricted ranges in the United States.

Sturnidae	European starling	*Sturnus vulgaris*
Vireonidae	Black-capped vireo	*Vireo atricapillus*
Parulidae	Golden-cheeked warbler	*Dendroica chrysoparia*
	Kirtland's warbler	*Dendrocia kirtlandii*
	Ovenbird	*Seiurus aurocapillus*
Passeridae	House or English sparrow	*Passer domesticus*
Emberizidae	Bobolink	*Dolichonyx oryzivorus*
	Eastern meadowlark	*Sturnella magna*
	Western meadowlark	*Sturnella neglecta*
	Yellow-headed blackbird	*Xanthocephalus xanthocephalus*
	Red-winged blackbird	*Agelaius phoeniceus*
	Tricolored blackbird	*Agelaius tricolor*
	Rusty blackbird	*Euphagus carolinus*
	Brewer's blackbird	*Euphagus cyanocephalus*
	Common grackle*	*Quiscalus quiscula*
	Brown-headed cowbird*	*Molothrus ater*
	Orioles	*Icterus* spp.
	Northern oriole	*Icterus galbula*
	Northern cardinal	*Cardinalis cardinalis*
	Grosbeaks**	
	House finch or linnet	*Carpodacus mexicanus*
	American goldfinch	*Carduelis tristis*
	Lesser goldfinch	*Carduelis psaltria*
	Dickcissel	*Spiza americana*
	White-crowned sparrow	*Zonotrichia leucophrys*
	Golden-crowned sparrow	*Zonotrichia atricapilla*

Chihuahuan raven	*Corvus cryptoleucus*
Southern U.S., generally near Mexican border	
Fish crow	*Corvus ossifragus*
Southeastern U.S., generally coastal	

*Species resembling widespread pest species.
**Four species representing three genera of grosbeaks are widely distributed in the U.S.

Northwestern crow Extreme northwestern U.S., coastal	*Corvus caurinus*
Bohemian waxwing Summer range is northwestern Canada and Alaska	*Bombycilla garrulus*
Great-tailed grackle Southwestern U.S.	*Quiscalus mexicanus*
Boat-tailed grackle Florida and coastal southeastern U.S.	*Quiscalus major*
Bronzed cowbird Extreme southwestern U.S.	*Molothrus aeneus*

APPENDIX B:

SELECTED EXAMPLES OF FOOD CONSUMPTION BY BIRDS

1. A captive black and white warbler daily consumed 80 percent of her weight in grasshoppers (Nice and Nice 1950).

2. Captive woodcocks daily ate their weight in earthworms (Sheldon 1971).

3. A single bobwhite quail ate 1000 grasshoppers and 532 other insects in one day (Nice 1910). This same individual consumed 600 - 3,000 weed seeds daily.

4. Terres (1980) reported that a mallard shot in December (Louisiana) contained 102,400 primrose willow seeds in its stomach. Terres also reported that a yellow-billed cuckoo contained 250 tent catepillars in its stomach, another individual possessed 217 fall webworms, and a flicker's stomach contained 5,000 ants.

5. Graber and Graber (1983) found that migratory warblers in southern Illinois fed heavily on forest tree caterpillars and ingested 1.2 - 1.7 times their weight in larvae per day.

6. Beal (1897) reported that wintering tree sparrows in Iowa consumed 875 tons of weed seeds during one winter.

7. The total bird population in a Czechoslavakia forest consumed 25 percent of their weight in food each day (Turcek 1952).

8. The total bird community of Hubbard Brook Experimental Forrest in New Hampshire possesses an average ingestion rate of 73,858 kcal/ha/yr (Holmes and Sturges 1975). 77 to 88 percent of this energy is provided by invertebrates.

Although individual consumption rates by birds are impressive, and birds indeed suppress insect pests at the local level, bird communities are not important contributors to overall energy flux in forest ecosystems. Their average ingestion rate at Hubbard Brook represents 0.17 percent of net annual primary production (Holmes and Sturges 1975).

Wiens (1973) reported similar energetics for grassland bird communities. Despite low energy flow through the avian community, birds are complexly involved in forest community organization, since a large proportion of their spring/summer diet is derived from unusually high order trophic levels (e.g., third, fourth, etc.), and particularly the critical detrital food chains.

APPENDIX C:

STATE DIRECTORS, ANIMAL AND PLANT HEALTH INSPECTION SERVICES (APHIS), U.S. DEPARTMENT OF AGRICULTURE,

EASTERN REGION

Eastern Regional Office 215 Centerview Dr, suite 104 Brentwood, TN 37027	George R. (Buddy) Abraham Eastern Regional Director COMM: 615/736-5095

STATE OFFICES

ARKANSAS

55 Post Office Building 600 W. Capitol Ave. Little Rock, AR 72201	Thurman W. Booth, Jr. State Director COMM: 501/378-5382

FLORIDA

227 N. Bronough St., Suite 227 Tallahassee, FL 32301	Richard L. Thompson State Director COMM: 904/681-7459

GEORGIA

School of Forest Resources University of Georgia Athens, GA 30602	Douglas I. Hall State Director COMM: 404/546-2020

ILLINOIS

Federal Building, Room 104 600 E. Monroe St. Springfield, IL 62701	Ronald Ogden State Director COMM: 217/492-4308

INDIANA

Entomology Hall, Room B-14 Purdue University West Lafayette, IN 47907	Vacant State Director COMM: 317/494-6229

LOUISIANA

Rm 271, Parker Coliseum LSU P.O. Box 25315 Baton Rouge, LA 70894-5315	Dwight LeBlanc State Director COMM: 504/389-0229

MAINE

Federal Bldg, Room 506A
40 Western Avenue
P.O. Box 800
Augusta, ME 04330-0800

Alfred Godin
State Director
COMM: 207/622-8262

MARYLAND-DELAWARE-DISTRICT OF COLUMBIA

1825B Virginia St.
Annapolis, MD 21401

Les Terry
State Director
COMM: 301/269-0057

MASSACHUSETTS-RHODE ISLAND-CONNECTICUT

463 West St.
Amherst, MA 01002

Vacant
State Director
COMM: 413/253-2403

MICHIGAN

108 Spring St.
St. Johns, MI 48879

Douglas Parr
State Director
COMM: 517/224-9517

MINNESOTA

316 North Robert St.
162 Federal Courts Bldg.
St. Paul, MN 551011

Richard S. Wetzel
State Director
COMM: 612/290-3157

MISSISSIPPI-ALABAMA

P.O. Drawer FW
Room 316, Dorman Hall
Mississippi State University
Mississippi State, MS 39762

Frank L. Boyd
State Director
COMM: 601/325-3014

MISSOURI-IOWA

Federal Bldg., Room 259-C
601 E. 12th St.
Kansas City, MO 64106

Lyle Stemmerman
State Director
COMM: 816/426-6166

NEW HAMPSHIRE-VERMONT

P.O. Box 2398
Concord, NH 03302-2398

Dennis Slate
State Director
COMM: 603/225-1416

NEW JERSEY-PENNSYLVANIA

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Basking Ridge, NJ 07920

Edwin Butler
State Director
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James Forbes
State Director
COMM: 518/472-6492

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Donald T. Harke
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Wells Stephensen
State Director
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Phoenix, AZ 85019

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State Director
COMM: 602/261-4010

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Scaramento, CA 95825

Ronald A. Thompson
State Director
COMM: 916/978-4621

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Grand Junction, CO 81505

H. Alan Foster
State Director
COMM: 303/245-9818

IDAHO

4696 Overland
Boise, ID 83705

Vacant
State Director
COMM: 208/334-1440

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P. O. Box 1938
Billings, MT 59103

William W. Rightmire
State Director
COMM: 406/657-6464

NEBRASKA

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Lincoln, NB 68508

Charles S. Brown
State Director
COMM: 402/437-5097

NEVADA

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Building C
Renoi, NV

Gilbert L. Marrujo
State Director
COMM: 702/784-5081

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Albuquerque, NM 87112

Gary L. Nunley
State Director
COMM: 505/766-3474

NORTH DAKOTA

1500 Capitol Ave.
Bismark, ND 58501

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State Director
COMM: 405/521-4040

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State Director
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State Director
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State Director
COMM: 512/229-5535

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Gary E. Larson
State Director
COMM: 801/524-5629

WASHINGTON-HAWAII

3625 93rd Ave., SW Olympia, WA 98502	Gary Oldenburg State Director COMM: 206/753-9884
P. O. Box 50225 300 Alamoana Blvd. Room 3316-B Honolulu, HI 96850	Timothy Ohashi District Supervisor COMM: 808/541-3063

WYOMING

P.O. Box 59 Casper, WY 82602	Robert N. Reynolds State Director COMM: 307/261-5336

APPENDIX D:

BIRD DAMAGE CONTROL PRODUCTS AND THEIR VENDORS

Exclusion

Hardware Cloth

Valentine Equipment Co.
9706 S. Industrial Drive
Bridgeville, IL 60455
(312) 599-1101

UV-Stabilized Polypropylene Netting and Screening

Conwed®

Almac Plastics Inc.
6311 Erdman
Baltimore, MD 21205-3585
(301) 485-9100

Conwed Corporation
Plastics Division
P.O. Box 43237
St. Paul, MN 55164-0237
(612) 221-1260

Green Valley Blueberry Farm
9345 Ross Station Rd.
Sebastopol, CA 95472
(707) 887-7496

Internet Inc.
2730 Nevada Ave. N.
Minneapolis, MN 55427
(612) 541-9690

Nixalite of America
1025 16th Ave.
P.O. Box 727
East Moline, IL 61244
(309) 755-8771

Orchard Supply Co. of Sacramento
P.O. Box 956
Sacramento, CA 95804
(916) 446-7821

Teitzel's Rainier View Blueberry Farms
7720 E. 134th Avenue
Puyallup, WA 98371
(206) 863-6548

Wildlife Control Technology
6408 S. Fig St.
Fresno, CA 93706
(209) 268-1200

Toprite*

J.A. Cissel Co. Inc.
P.O. Box 339
Farmingdale, NJ 07727
(201) 938-6600

Polyvinyl Chloride (PVC) Covered Polyester Yarn Netting

Conservare Pigeon Control

ProSoCo, Inc.
P.O. Box 1578
Kansas City, KS 66117
(913) 281-2700
111 Snyder Road
South Plainfield, NJ
(201) 754-4410

1601 Rock Mountain Blvd.
Stone Mountain, GA 30083
(404) 939-9890

Traps*

Grand Rapids Audubon Club — Sparrows
54 Jefferson Ave. SE
Grand Rapids, MI 49503
Kroener Martin/Bluebird House Trap

*Most bird traps are "home-made."

Last Perch Box 426 Mitchellville, IA 50169 (515) 967-2853	Sparrows
Mustang Manufacturing Co P.O. Box 10947 Houston, TX 77018 (713) 682-0811	Pigeons, Starlings, Sparrows
The Nature Society Purple Martin Junction Griggsville, IL 62340	Sparrows
Tomahawk Live Trap Co. P.O. Box 323 Tomahawk, WI 54487 (715) 453-3550	Pigeons, Sparrows
Woodstream Corp. Lititz, PA 17543 (717) 626-2125 Havahart® Victor® Tender Trap	Pigeons, Sparrows

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Avitrol Corp.
320 S. Bonton Ave., Suite 514
Tulsa, OK 74103
(918) 582-3359

Wetting Agents

Contact State Animal Damage Control Agency.

Repellents

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Bird Barrier
Bird Barrier Inc.
18811 Crenshaw Place
Room #101
Torrance, CA 90504
(213) 217-1222

Cat Claw®
Shaw Steeple Jacks Inc.
2710 Bedford St.
Johnstown, PA 15904
(814) 266-8008

Nixalite®
Nixalite of America
1025 16th Ave.
P.O. Box 727
East Moline, IL 61244
(309) 755-8771

Electrical Shock

Avi-Away®
Avi-Away Division
Monarch Molding Inc.
120 Liberty St.
Council Grove, KS 66846
(316) 767-5115

Sticky Contacts

Bird Repellent GB 1102
ArChem Corp.
1514 11th Street
P.O. Box 767
Portsmouth, OH 45662
(614) 353-1125

Bird Tanglefoot®
Forestry Suppliers, Inc.
205 W. Rankin St.
P.O. Box 8397
Jackson, MS 39204
800-647-5368
800-682-5397 (In Mississippi)

The Tanglefoot Co.
314 Straight Ave. SW
Grand Rapids, MI 49504
(616) 459-4130

Excelcide Bird Repellent
The Huge Co.
7625 Page Blvd.
St. Louis, MO 63133

Preferred Brand
Sun Pest Control
2945 McGee Trafficway
Kansas City, MO 64108
(816) 561-2174

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Baumes Castorine Co.
200 Matthew St.
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(315) 336-8154

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Chicago, IL 60611
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(216) 425-7801

Other Suppliers
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(314) 533-0999

J.C. Ehrlich Chemical Co.
State College Laboratories
840 William Lane
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Borderland Products Inc.
P.O. Box 366
Buffalo, NY 14240
(716) 825-3300

Mesurol®
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Chemagro Division
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Kansas City, MO 64120
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(215) 675-7200

C. Frensch Ltd.
168 Main Street E., Box 67
Grimsby, Ontario L3M 4G1
Canada
(416) 945-3817

Hub States Corp.
1000 N. Illinois St.
Indianapolis, IN 46202

B. M. Lawrence & Co.
24 California St.
San Francisco, CA 94111
(415) 981-3650

Pisces Industries
P.O. Box 6407
Modesto, CA 95355
(209) 578-5502

Reed-Joseph International Co.
P.O. Box 894
Greenville, MS 38702
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Smith-Roles
1367 S. Anna St.
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(316) 945-0295; (701) 852-3726

Teiso Kasei Co. Ltd.
350 S. Figueroa St., Suite 350
Los Angeles, CA 90071
(231) 680-4349

Wildlife Control Division
Margo Supplies, LTD.
Site 8, Box 2, RR #6
Calgary, Alberta
T2M 4LS, Canada
(403) 285-9731

Pyrotechnics

Clow Seed Co.
1081 Harking Rd.
Salinas, CA 93901
(408) 422-9693
(whistlers, bird bombs)

J. E. Fricke, Co.
40 N. Front St.
Philadelphia, PA 19106
(fuse rope)

Marshall Hyde Inc.
P.O. Box 497
Port Huron, MI 48060
(313) 982-2140

Munitions Filling Factory
St. Marys, New South Wales,
Australia
(shell-crackers)

New Jersey Fireworks Co.
Box 118
Vineland, NJ 08360
(609) 692-8030
(rope firecrackers)

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Sutton Ag Enterprises
1081 Harkins Rd.
Salinas, CA 93901
(408) 422-9693

Wald & Co.
208 Broadway
Kansas City, MO 64105
(816) 842-9299
(rope firecrackers)

Western Fireworks Co.
2542 SE 13th Avenue
Canby, OR 97013
(503) 266-7770

Wildlife Control Division
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(bird bombs, racket bombs)

Alarm/Distress Calls (Recorded)

Applied Electronics Corp.
3003 County Line Rd.
Little Rock, AR 72201
(501) 821-3095

Schmidt, R. H., and H. L. Johnson. 1982.
Dispersal recordings, source of supply
Order from:
Department of Forestry
Fisheries and Wildlife
202 Natural Resources Hall
University of Nebraska
Lincoln, NB 68583

Signal Broadcasting Co.
2314 Broadway St.
Denver, CO 80205
(303) 571-5649
(Sells copies of Denver Wildlife Research Center calls)

Smith's Game Calls
P.O. Box 236
Summerville, PA 15864
(starling distress call)

Wildlife Technology
P.O. Box 1061
Hollister, CA 95023
(rents recordings of alarm and distress calls)

Electronic Noises

Av-Alarm Corp.
675-D Conger St.
Eugene, OR 97402
(503) 342-1271

Bird-X
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Chicago, IL 60610
(312) 648-2191

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Margo Supplies, LTD.
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(403) 285-9731

Other Acoustics

Falcon Safety Products Inc.
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Mountainside, NJ 07092
(201) 233-5000
(air horn)

Tomko Enterprises Inc.
Route 58, RD #2
P.O. Box 937-A
Riverhead, NY 11901
(516) 727-3932
(clapper device with timer)

Lights (Flashing or Revolving)

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Chicago, IL 60610
(312) 648-2191

R. E. Dietz Co.
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Syracuse, NY 13201
(315) 424-7400

The Huge Co.
7625 Page Blvd.
St. Louis, MO 63133
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Tripp-Lite Manufacturing Co.
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(312) 329-1777

Models (Predators, Kites, and Balloons)

Atmospheric Instrumentation
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1880 S. Flatiron Ct., Suite A
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(suspended hawk model)

Clow Seed Co.
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Salinas, CA 93901
(408) 422-9693
(hawk-kite model)

Cochranes of Oxford Ltd.
Leafield, Oxford
England, OX8 5NT
(099387-641)
(kites)

R. M. Fay
Rt. 2 Box 2569
Grandview, WA 95930
(509) 882-3258
(balloon supported hawk-kite model)

High-as-a-Kite
200 Gate Five Rd.
Sausalito, CA 94965
(415) 332-6355
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The Huge Co., Inc.
P.O. Box 24198
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(owl model)

Raven Industries, Inc.
P.O. Box 1007
Sioux Falls, SD 57117
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Saturn Inc.
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Kathryn, ND 58049
(701) 924-8645
(pop-up owl model with distress call
of red-winged blackbird)

Sutton Ag Enterprises
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Salinas, CA 93901
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(kites)

Teiso Kasei Co. Ltd.
350 S. Figueroa St., Suite 350
Los Angeles, CA 90071
(213)680-4349
(hawk-kite model)

Tiderider Inc.
P.O. Box 9
Eastern and Steele Blvds.
Baldwin, NY 11510
(516) 223-3838
(kites)

WeatherMeasure Corp.
P.O. Box 41257
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Dallas, TX 75220
(214) 357-5741

J. C. Ehrlich Chemical Co.
State College Laboratories
840 William Lane
Reading, PA 19612
(215) 921-0641

4-Aminopyridine

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320 S. Boston Ave., Suite 514
Tulsa, OK 74103
(918) 582-3359

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Starlicide®

Ralston Purina Co.
Checkerboard Square
St. Louis, MO 63164
(314) 982-1000

Toxic Perches

Rid-A-Bird Inc.
1224 Grandview Ave.
P.O. Box 22
Muscatine, IA 52761
(319) 263-7970

APPENDIX E:

CHEMICAL NOMENCLATURE OF COMPOUNDS USED FOR BIRD DAMAGE CONTROL

Avitrol®	4-aminopyridine (hydrochloride)*
CAT	2-chloro-4-acetotoluidine
Crow Chex®	copper oxalate
Curb	aluminum ammonium sulfate
DRC-1339	3-chloro-p-toluidine hydrochloride
Endrin	Mostly hexachloroepoxyoctahydro-endo, endo-dimethanonaphthalene
FC Corn Chops-99S	4-aminopyridine (hydrochloride)*
Fenthion	O,O-dimethyl O-[3-methyl-4-(methylthio) phenyl] phosphorothioate
Methiocarb	3,5-dimethyl-4-(methylthio) phenyl methylcarbamate
Ornitrol®	20,25-diazacholesterol dihydrochloride
PA-14 (Tergitol)	α-alkyl (C_{11} - C_{15})-omega-hydroxypoly (oxyethylene)
Starlicide®	3-chloro-p-toluidine hydrochloride
Strychnine	2,4a,5,5a,7,8,15,15a,15b,15c,-dechydro-4,6-methano-6H,14H-indolo [3,2,1-ij] oxepino[2,3,4-de] pyrrolo [2,3-h] quinolin-14-one
4-AP	4-aminopyridine (hydrochloride)*

*The hydrochloride derivative is generally used since it is more stable.

APPENDIX F:

NATIONALLY REGISTERED BIRD CONTROL CHEMICALS*

Active Ingredient	Target Species	Action
Strychnine	Pigeons English sparrows Magpies Horned larks Finches	Oral toxicant
3-chloro-p-toluidine HCL (DRC-1339) (Starlicide®)	Starlings Pigeons Gulls Crows Blackbirds Ravens	Oral toxicant
Endrin	English sparrows Starlings Pigeons	Contact toxicant
Fenthion	English sparrows Starlings Pigeons	Contact toxicant
Tergitol 15-S9 (PA-14)	Blackbirds Starlings Cowbirds Grackles	Lethal hypothermic stressing agent
4-Aminopyridine (AVITROL®)	Gulls Blackbirds English sparrows Starlings Cowbirds Grackles Crows	Lethal repellent
Naphthalene**	Starlings Pigeons English sparrows	Odor repellent

*Adapted by Ed Cleary From Eschen, M. S. and E. W. Schafer. 1986. "Registered Bird Damage Control Chemicals" (Unpublished).

**The effectiveness of naphthalene as a bird repellent has recently been challenged. See Dolbeer, R. A., M. A. Link, and P. P. Woronecki. 1988. "Napthalene shows no repellency for starlings," Wildlife Society Bulletin, Vol 16, pp 62-64.

Active Ingredient	Target Species	Action
Polyisobutylene	birds	Tactile repellent
Polybutene	birds	Tactile repellent
Methiocarb	Blackbirds Pheasants	Taste repellent Corn seed treatment
Methiocarb (Registration questionable)	Blackbirds Starlings English sparrows Finches Jays Orioles Robins	Taste repellent Blueberries Sweet Cherries Sour Cherries Grapes
Methiocarb (Registration questionable	birds	Taste repellent Corn Peppers
Methiocarb (Registration questionable)	Cowbirds Grackles English sparrows Crows Doves	Tasterepellent Nursery trees Seeds
Copper Oxalate	Crows	Taste repellent Corn seed treatment
Thiram	birds	Taste repellent Conifer seed treatment
Lindane Captan Powder	Pheasants	Taste repellent Seed treatment
Lindane	Pheasants	Taste repellent Seed treatment
Capsicum Allium	Starlings English sparrows Larks Finches	Taste repellent Sprouting crops Fruits Grains Nuts

Active Ingredient	Target Species	Action
Coal Tar Creosote Liquid	Crows	Taste repellent Corn seed treatment
Azacosterol (Ornitrol®)	Pigeons	Reproductive inhibitor

APPENDIX G:

TOXICITY OF STARLICIDE® TO SELECTED BIRD AND MAMMAL SPECIES (Timm 1983b, after DeCino et al. 1966 and Clark 1975)

Bird	Approximate LD_{50} acute oral* mg/kg
Sturnidae	
Starling *Sturnus vulgaris*	3.8
Icteridae	
Red-winged blackbird *Agelaius phoeniceus*	1.8-3.2
Columbidae	
Mourning dove *Zenaidura macroura*	5.6-10.0
Pigeon (Rock dove) *Columba livia*	17.7
Phasianidae	
Ring-necked pheasant *Phasianus colchicus*	10
Coturnix quail *Coturnix coturnix*	< 10
Meleagrididae	
Domestic turkey *Meleagris gallopavo*	5.6
Anatidae	
Mallard duck *Anas platyrhynchos*	10-32
Blue-winged teal *Anas discors*	10-100
Pintail duck *Anas acuta*	>32
Corvidae	
Common crow *Corvus brachyrhynchos*	1.8
Black-billed magpie *Pica pica*	5.6-17.7
Blue jay *Cyanocitta cristata*	< 10
Accipitridae	
Cooper's hawk *Accipiter cooperii*	320-1,000
Marsh hawk, *Circus cyaneus*	100
Falconidae	
Kestrel (Sparrow hawk) *Falco sparverius*	>320
Ploceidae	
House sparrow *Passer domesticus*	320-448

*LD_{50} (mg/kg) is the milligram dose of toxin per kilogram body weight of species tested that kills 50 percent of the experimental subjects.

Mammal	LD_{50} acute oral mg/kg	No Kill mg/kg
White rats	1170-1770	
Mice	2000	
White mice	960	
Dogs		100
Sheep	400+	200
Cow		10

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